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D. M. BEACH, *Editor*

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APPLICATIONS OF AUTOMATIC TRAFFIC RECORDER DATA IN HIGHWAY PLANNING

BY THE DIVISION OF HIGHWAY TRANSPORT, PUBLIC ROADS ADMINISTRATION

Reported by L. E. PEABODY, Senior Highway Economist, and O. K. NORMANN, Associate Highway Economist

Automatic traffic recorders are being used in 46 States to obtain continuous records of traffic flow at more than 500 locations. Analysis of data from typical stations throughout the United States shows that there was an extremely wide variation in the ratios between traffic for maximum days or hours and the average annual daily traffic, but this variation was considerably less at locations in the southern States as compared with those in northern States. Traffic on the maximum day was normally 233 percent and the maximum hour 25.4 percent of the annual average daily traffic. It is uneconomical to design the average highway for a greater hourly volume than the value exceeded during the 30 peak hours each year, and little will be saved in the construction cost and a great deal lost in expediting the movement of traffic if the design will not handle the volume exceeded during the 50 peak hours. However, the variation in traffic flow between locations is such that detailed data are necessary for a complete engineering analysis of the traffic facilities required at any particular location.

Tests of various schedules of operation that are used in highway planning surveys indicate that eighteen 8-hour counts properly scheduled throughout the year produce results within practical limits of accuracy; that the short count schedule by single hours, or shorter periods, is not as accurate, and its use is limited to relatively compact areas such as a city where time loss and cost of travel may be reduced.

A study of the invariance in seasonal and other types of traffic variation over a period of several years provides a measure of the limitations in the use of factors in estimating annual traffic from observations covering but a small period of time, possibly a few hours. The rather remarkable uniformity in such factors provides considerable confidence in the accuracy of the estimates.

As the traffic records accumulate they will permit an analysis of the traffic trends at a large number of points widely distributed throughout the country and should furnish data useful in setting up regional or national business indices. The relatively brief record now available has already proved of value in making estimates of traffic increases on major segments of the highways and streets of the Nation.

ONLY a few years ago information with regard to the volume of motor-vehicle traffic by hours throughout the year was available only at a few bridges, where it was obtained incidental to the collection of tolls. Usually these data were summarized and reported only as an annual total or, at best, subtotals were obtainable by months. The need for complete traffic flow information was recognized, but until the State-wide highway planning surveys were begun no concerted effort was made to obtain such data on anything approaching a Nation-wide scale. Today, at more than 500 points throughout the country, and in nearly every State, traffic-flow information is being obtained by means of permanently installed traffic counters. At many hundreds of additional points this information is collected by means of portable traffic counters. The cost of this mechanical counting is but a small fraction of the cost of manual counting.

Since detailed traffic data are so recently available and the record correspondingly short, it is quite certain that not all of the practical uses of these data have developed. Indeed the record is so short that an adequate study of some applications of the data is not possible. Nevertheless, it is clear that the principal uses of these data are as follows: (1) In measuring the time during which a section of highway is congested, and the fraction of the year's traffic that moves under conditions of congestion; (2) in compiling a traffic record, obtained under widely varying climatic, geographic, and economic conditions, essential in planning extensive traffic surveys such as those forming a part of the highway planning surveys, and in which some traffic information is obtained for every mile of publicly used highway; (3) in acquiring knowledge of the variations in traffic volume required in expanding short traffic counts covering but a small fraction of the year to obtain reasonably accurate estimates of the traffic total for the year; and (4) the traffic record is of vital importance in the study of traffic trends and their relationships to economic factors and to probable future traffic. It is mainly with regard to the latter use that the record is inadequate; and this deficiency is being reduced as the records accumulate with each passing month and year.

The automatic traffic counters used in the State-wide highway planning surveys are of two general types; one designed to be installed permanently at key locations and referred to as a fixed-type recorder; and a portable counter used in obtaining short counts at a large number of widely separated locations.

AUTOMATIC RECORDERS YIELD HOURLY RECORDS OF TRAFFIC FLOW

The fixed-type machine[1] is much larger, more expensive, and more dependable than the portable traffic counter. The fixed-type machines are designed to count passing vehicles without counting pedestrians. Two parallel beams of light approximately 30 inches center to center, directed across the roadway upon photoelectric cells, must be interrupted simultaneously to operate the counting mechanism. Pedestrians, who interrupt only one beam at a time, are not counted by the machine. Every hour, on the hour, these machines stamp on a record tape the day, hour, and cumulative counter reading, thus producing an hourly record of the number of vehicles passing the location. The cost of one of these machines is approximately $400 and the average cost of installation is approximately $125 per machine. A survey of the operating costs in 1938 for all States using this equipment gave the average cost of operating one fixed-type automatic recorder at a rural location for a month as follows:

[1] The May 1938 issue of PUBLIC ROADS carries a detailed description of these machines.

Overhead		$4.87
Supervision		3.51
Maintenance:		
Labor	$7.64	
Subsistence	1.78	
Travel	8.86	
Power	4.36	
Supplies, etc	2.88	
Total maintenance		25.52
Preparation of records		10.09
Grand total		43.99

The portable-type traffic counters used in the planning surveys consist of two general types, the recording counter and the cumulative or nonrecording counter.[2] The recording-type machine produces records by printing or photographing the cumulative counter reading on a record tape every hour on the hour. The cumulative counter enables a record to be obtained only of the total traffic passing the machine between readings by an observer. In a few instances, cumulative counters have been equipped with a clock that starts and stops the machine at predetermined times, thus eliminating the necessity for placing the machine and picking it up at a definite time.

The operating mechanisms of the portable counters are of two types—electrically operated and mechanically operated. The majority of the mechanically operated machines are an adaptation of a watch or clock, so arranged that the escapement is operated when the wheels of a vehicle pass over the detector. These counters have generally been referred to as watch-type counters. So far this type of construction has been confined to cumulative counters. However, work is in progress to develop a recording counter that will be entirely spring operated.

Most of the portable machines now in operation make use of a pneumatic detector consisting of a rubber tube placed across the roadway and a diaphragm of some flexible material at one end of the tube. The air impulse produced when each pair of wheels of a vehicle passes over the tube causes the diaphragm to move, which, in turn, either actuates the contacting elements controlling the counting circuit, or operates directly the escapement of the counting mechanism. Other detectors used with portable machines are a photoelectric device using one light beam, and a positive-contact device consisting of two strips of spring steel, enclosed in a waterproof casing, which make contact when pressed together by the wheels of a vehicle passing over them.

The cost of portable counters ranges from $10 for the watch-type cumulative counter to $225 for the hourly recording type machine. A number of States have constructed cumulative counters of the electrically operated type at a cost of approximately $25 per machine, all of which use the pneumatic detector. One State has constructed recording counters using the pneumatic detector at a cost of approximately $80 per machine. Another State has constructed a portable counter using a photoelectric detector with a photographic recording device at a cost of approximately $125 per machine.

The portable traffic recorders have not been in use a sufficient length of time for the cost of their operation to have been accurately determined. One difficulty in determining the cost of records is that it depends almost entirely on the distance between stations and the schedule upon which they are operated. One State has reported a total cost of $1.62 per count for 24-hour counts obtained with the simple cumulative counter. This cost includes salary, mileage, parts, power, and incidentals. Another State reports a total cost of approximately 87 cents per 24-hour count. These figures are for eastern States where stations are close together. The estimated monthly cost of operation (parts, batteries, and incidentals) is $4 for one of the recording-type portable machines. The operating cost of the cumulative counters is less than that, so it is very evident that the charges for salary and mileage are the major part of the cost of counting traffic with portable traffic counters.

Experimental development and field tests of the automatic traffic counters were carried on throughout 1935, and 84 of the fixed-type machines were placed in operation by the States during 1936. In 1937, 115 additional fixed-type counters were installed; in 1938, 120; in 1939, 168; and up to July 1940, 45 new fixed-type machines were placed in operation. A total of 532 such machines were in operation during July 1940. A complete statement of the record, by States, is given in table 1, and the locations of these machines are indicated in figures 1, 2, and 3.

Locations for the machines were chosen by the States with the assistance of the Public Roads Administration. Detailed knowledge of economic areas within the States and of the character of traffic using individual routes were factors in the selection of locations. Consequently, farm-to-market roads, roads used largely by tourist traffic, and roads upon which intercity commercial traffic is a considerable fraction of total traffic, are included among the locations.

To obtain information regarding the fluctuation of traffic flow on primary highways, automatic traffic counter records for 90 stations located on the main U. S. numbered highways have been analyzed. In selecting record stations for analysis, an attempt was made to include scattered locations so that the figures for annual traffic volumes would cover a wide range and be geographically distributed throughout all sections of the United States. The traffic records for each of the selected stations show the number of vehicles for almost each hour during at least 1 full year.

FLUCTUATIONS IN TRAFFIC FLOW GREATER IN NORTH THAN IN SOUTH

Table 2 shows the location, the period used for the analysis, and the annual average 24-hour traffic volume for each of the stations. Stations located in 43 States and having annual average 24-hour traffic volumes ranging from 311 to 13,624 vehicles were used.

Figure 4 shows the maximum 24-hour traffic volume at each location during the year, plotted against the annual average 24-hour traffic volume. For any annual volume, there is a large variation in the peak day during the year. For example, the roads with an annual average of about 4,000 vehicles per day have from 6,000 to 18,000 vehicles on the peak day, or a variation of 300 percent. The average shown by the

[2] A simple counter of this type is described in the January 1939 issue of PUBLIC ROADS.

solid line indicates that there is a slight drop from a straight-line relationship as the volume increases. For sections that have annual averages between 2,000 and 4,000 vehicles there is a marked sag in the curve. On an average, the maximum 24-hour traffic volume was 2.45, 2.20, and 2.34 times the annual average 24-hour volume for locations with annual averages below 2,000, between 2,000 and 4,000 and over 4,000 vehicles, respectively.

TABLE 1.—*Number of automatic traffic counters*[1] *which started operation in various years*

State	1936	1937	1938	1939	1940
Alabama		9		1	
Arizona	7				
Arkansas			11	5	
California		10			
Colorado	1		2	3	
Connecticut				20	
Florida	6		4		2
Georgia				12	
Idaho	4				
Illinois			1	5	
Indiana	4			14	
Iowa	2		10	12	
Kansas	1		3		
Kentucky		4	2	5	
Louisiana		2	2	4	
Maine			6		
Maryland		10	1	2	
Massachusetts			8		1
Michigan	1	8	1		
Minnesota	9	2		16	6
Mississippi				10	
Missouri		5	7	5	1
Montana			6	8	
Nebraska	5		2		
Nevada	1	7	2	2	1
New Hampshire		3			
New Mexico	9		1		
New York			12	9	
North Carolina			4		
North Dakota	3		2	4	
Ohio	2		5		10
Oklahoma	9				11
Oregon	2	3			
Pennsylvania	1	20	1	1	7
Rhode Island		4			
South Carolina		1	6	6	
South Dakota		5			3
Tennessee		4			
Texas	4	10	2	14	1
Utah	2		4		2
Vermont		1		3	
Virginia			4		
Washington	3	7			
West Virginia	4			7	
Wisconsin	4		8		
Wyoming			3		
Total	84	115	120	168	45
Cumulative total	84	199	319	487	532

[1] Machines operating in July 1940.

TABLE 2.—*Location of automatic traffic recorders used to obtain data for study of fluctuation in traffic density*

State	Location		Period used		Annual average 24-hour traffic volume
	State's recorder station No.	United States route No.	From—	To—	
Alabama	2	72	1- 1-39	12-31-39	531
	4	78	12-25-37	12-24-38	1,073
Arizona	1	60, 70, 80	7- 7-39	7- 6-40	7,174
	4	60 and 89	1-28-39	1-27-40	1,743
Arkansas	11	63	1- 1-39	12-31-39	311
California	1	99	7-10-37	7- 9-38	5,815
	2	99	2-20-37	2-19-38	2,281
Colorado	3	85-87	2-27-37	2-26-38	4,334
	11	85	6-26-38	6-25-39	5,472
Connecticut	6 and 7	Merritt Parkway	3-31-39	3-30-40	13,624
	17	5	3-31-39	3-30-40	8,313
Florida	1	90	11-27-38	11-26-38	749
	3	41	1- 1-38	12-31-38	1,668
	4	90	5-15-37	5-14-38	3,365
Georgia	1	41 and 411	1- 1-39	12-31-39	3,238
	12	84	1- 1-39	12-31-39	632
Idaho	1	10	1- 1-38	12-31-38	2,438
	2	30	4- 3-37	4- 2-38	3,085
	3	30	1- 1-38	12-31-38	2,290
Illinois	1	45	9-27-36	9-26-37	4,057
	2	66	1-24-37	1-23-38	3,937
	7	50	12-18-37	12-17-38	3,210
Indiana	2A	20	8-28-37	8-27-38	3,490
	42A	52	7- 3-37	7- 2-38	3,071
	59A	40	1-15-38	1-14-39	3,125
	72A	31	1-15-38	1-14-39	2,293
Iowa	601	65-69	12-19-36	12-18-37	3,290
	601	65-69	1- 1-38	12-31-38	3,539
Kansas	3	50S	2-18-39	2-17-40	2,059
	5	24 and 40	8-14-38	8-13-39	2,183
Louisiana	1	79-80	12-25-37	12-24-38	3,304
	4	90	4-24-37	4-23-38	4,226
Maine	2	1	2- 5-38	2- 4-39	1,287
Maryland	2	40	4- 3-37	4- 2-38	3,030
	12	40	1-22-38	1-21-39	7,250
Massachusetts	8	1	4-30-38	4-29-39	7,363
	10	6	7-21-39	7-20-40	6,476
Michigan	676	27	10- 2-37	10- 1-38	3,151
	678	23	1- 1-39	12-31-39	1,200
Minnesota	157	212-169	3-20-37	3-19-38	4,875
	159	10-52 and 169	9-11-37	9-10-38	3,730
	175	52	7- 3-37	7- 2-38	872
Missouri	5	54	7-17-37	7-16-38	1,708
	9	66	1-23-39	1-22-40	5,220
Wyoming	205	20	5-19-39	5-18-40	1,309
	204	30	1- 1-39	12-31-39	1,257
Montana	A4	10-12	10-29-38	10-28-39	982
	A7	91	6-30-39	6-29-40	495
Nebraska	2	30	1- 8-38	1- 7-39	1,619
	5	6	1- 8-38	1- 7-39	2,128
Nevada	101	40	11- 6-37	11- 5-38	1,469
	107	40	6- 5-37	6- 4-38	755
New Hampshire	1	3	9-18-37	9-17-38	1,360
New Mexico	1	85-285	6-12-37	6-11-38	1,216
	6	66	1-15-38	1-14-39	1,574
	7	70-80	8- 7-37	8- 6-38	1,461
	9	54-70	1- 8-38	1- 7-39	751
New York	5-1	5 [1]	12-31-38	12-30-39	4,458
North Carolina	3	29	1- 1-39	12-31-39	4,296
	4	19 and 23	2-25-39	2-24-40	2,540
North Dakota	102	1 [1]	2- 1-39	1-31-40	356
	103	2	10-18-37	10-17-38	352
Ohio	25	42	4-12-39	4-11-40	3,645
	27	25-68	2-18-39	2-17-40	3,928
Oklahoma	1	66-69	5-15-37	5-14-38	2,111
	5	77	2-27-37	2-26-38	2,259
Oregon	Rowena (3).	30	11-27-37	11-26-38	1,261
Pennsylvania	1	20	11-20-37	11-19-38	4,395
	4	6	7-24-37	7-23-38	1,231
Rhode Island	2	1-A [1]	6- 4-38	6- 3-39	1,931
South Carolina	2	15-52	12- 4-37	12- 3-38	1,583
	105	29	2-20-37	2-19-38	3,936
South Dakota	101	14-16	5-15-37	5-14-38	982
	106	18	12-31-38	12-30-39	479
Tennessee	1	31W	4-21-39	4-20-40	3,425
Texas	1	80	7- 7-39	7- 6-40	9,053
	4	77-81	1- 1-38	12-31-38	4,049
	5	80	12-19-36	12-18-37	2,427
	8	81-83	3-20-37	3-19-38	875
Utah	301	40	11-13-37	11-12-38	1,766
	302	50-91	7-10-37	7- 9-38	3,443
Vermont	A-12-2	2	11-28-36	11-27-37	1,615
Virginia	1	1	6-26-37	6-25-38	6,668
	4A	58	1-31-39	1-30-40	2,429
Washington	1	99	12-28-37	12-27-38	3,590
	3	99, 410, 101	9-11-37	9-10-38	3,385
	4	99	12-11-37	12-10-38	3,479
	10	10	4-10-37	4- 9-38	3,233
Wisconsin	2 and 3	41	1- 8-38	1- 7-39	5,614
	10	10 and 12	1- 9-37	1- 8-38	1,632

[1] State route.

An investigation of the surface width at each location showed that all stations with annual averages below 3,400 vehicles had 2 traffic lanes. As the annual average increased above 3,400, the relative number of sections wider than 2 lanes increased until at 4,500 vehicles practically all sections had more than 2 lanes. It, therefore, seems that the sag in the curve was due to a tendency for some drivers to avoid heavily traveled 2-lane highways on days of peak traffic.

A classification of the stations by their geographic location showed that at stations in the North, where there usually is considerable snow and ice each winter

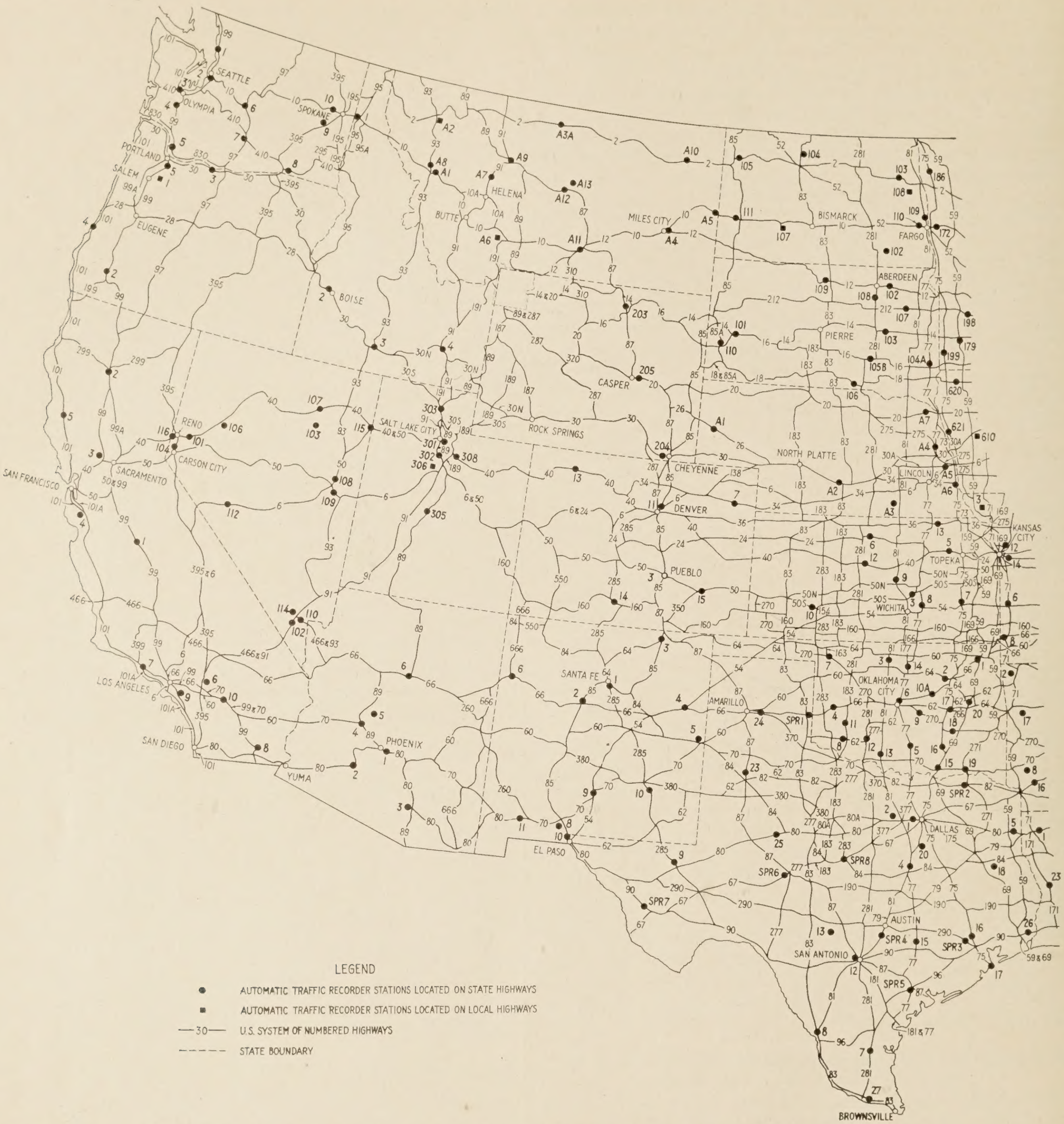

FIGURE 1.—LOCATION OF AUTOMATIC TRAFFIC RECORDER STATIONS IN WESTERN STATES.

the number of vehicles during the maximum day averaged 2.6 times the number on the average day while in the South there were only 1.8 times as many vehicles on the maximum day as on the average day. The curves for both the northern and southern locations (fig. 4) show the same general tendency for the slope of the curves to decrease when the annual volume reaches about 2,000 vehicles per day and then to increase and return nearly to the former slope at between 4,000 and 4,500 vehicles per day.

Figure 5 shows the tenth highest 24-hour traffic volume for each station plotted against the annual average 24-hour volume. The variation in the tenth highest values for any particular annual average 24-hour volume is considerably less than for the maximum 24-hour volume. On an average, the traffic volume on the tenth highest day is 1.75 as great as the annual average 24-hour volume. Corresponding figures for the locations in the northern and southern States are 1.88 and 1.44, respectively. In other respects, the curves are very similar to those for the maximum days. The tenth highest day was selected as an index because it is felt that it represents the conditions that should be expected on an average Sunday in summertime.

Figure 6 shows the same average curves as those presented in figures 4 and 5, together with curves for

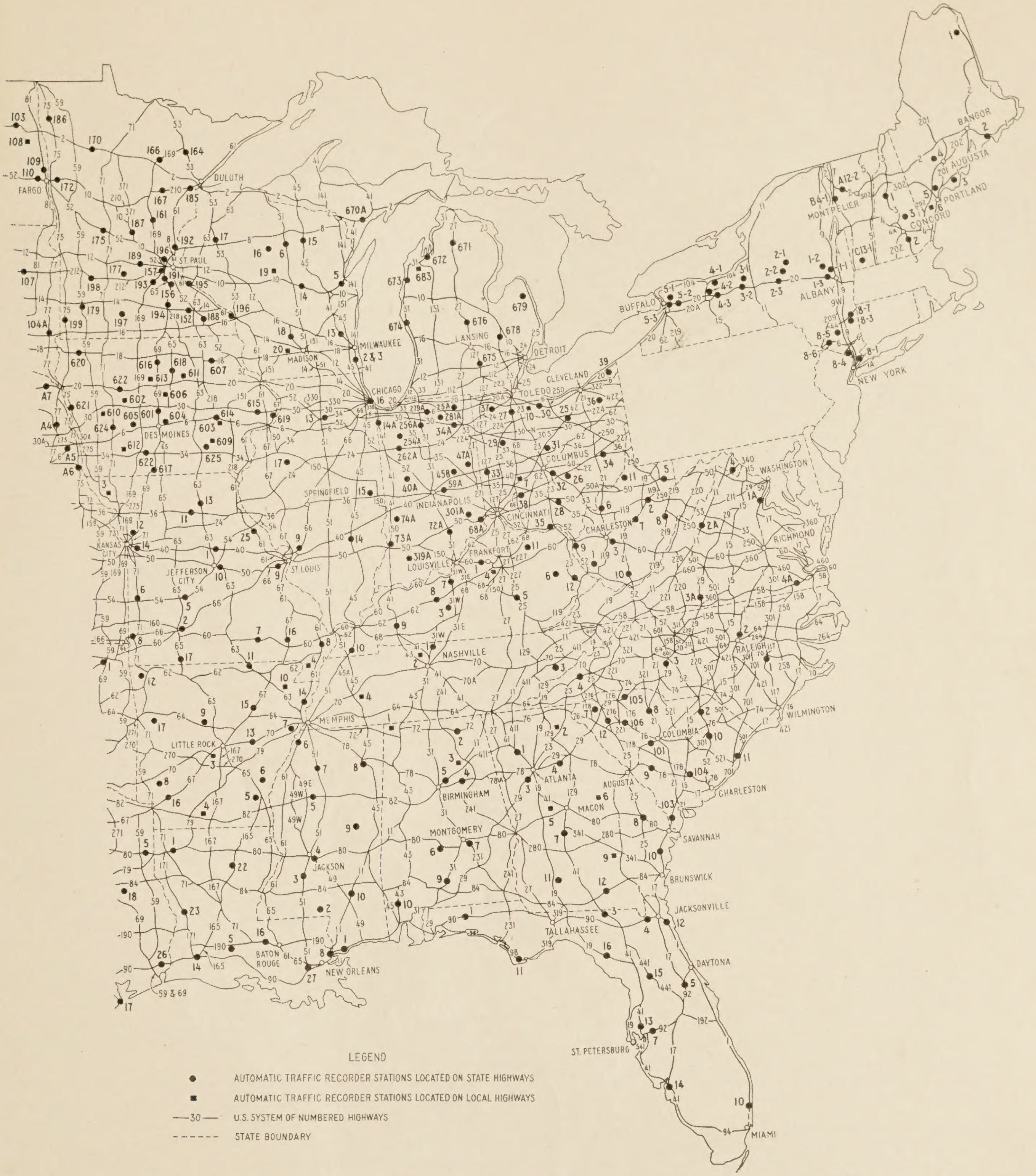

FIGURE 2.—LOCATION OF AUTOMATIC TRAFFIC RECORDER STATIONS IN EASTERN STATES.

the average 24-hour volumes during the maximum week and maximum month. The slope of each of the curves as obtained from the original data decreased slightly when the annual average reached about 2,000 vehicles and then increased until at an annual average of about 4,500 the former slope was nearly reached. Since the reason for this was probably due to congested conditions on a number of the roads in this group, the relations shown by the curves on figure 6 are more useful when considering design features to accommodate the various traffic volumes. However, figure 7 illustrates that even these curves are of little value in determining maximums from the annual average since there is a large variation between different stations. For example, although the volume on the maximum day for the average location is 2.32 times as high as the volume on

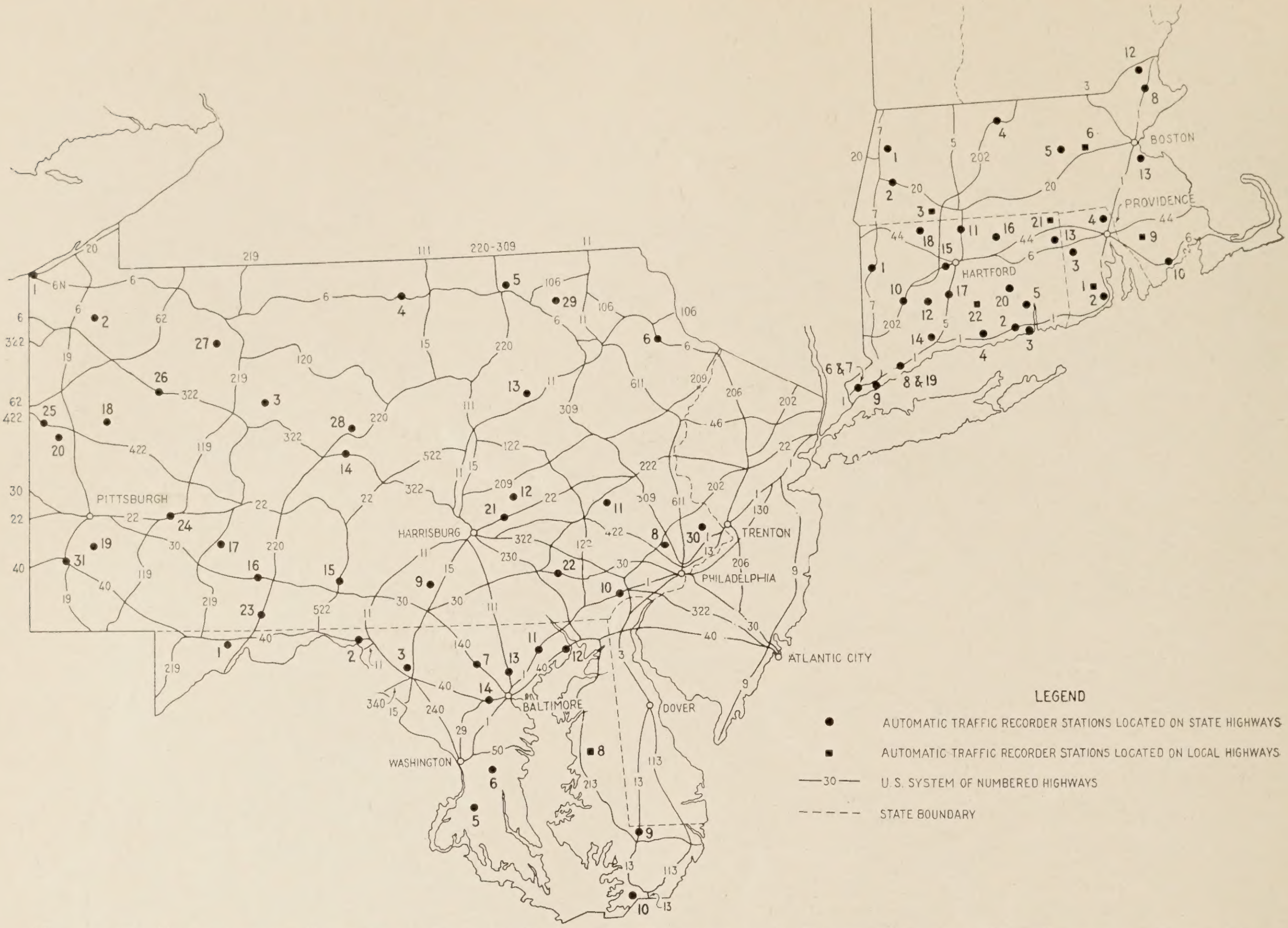

FIGURE 3.—LOCATION OF AUTOMATIC TRAFFIC RECORDER STATIONS IN 7 EASTERN STATES NOT SHOWN IN FIGURE 2.

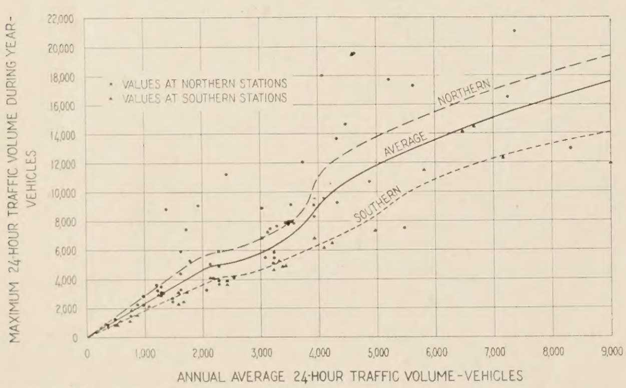

FIGURE 4.—MAXIMUM 24-HOUR TRAFFIC VOLUME DURING 1 YEAR FOR VARIOUS ANNUAL AVERAGE 24-HOUR TRAFFIC VOLUMES.

the average day, the group ranging from 1.4 to 1.8 includes a larger percentage of the locations than any other group covering a similar range. In all cases, the maximum values for the southern stations do not cover as great a range as the northern stations and the values for the southern stations are closer to the annual averages.

Figure 8 shows, for different annual average 24-hour traffic volumes, the average number of days during a year that the traffic volume exceeded various values. Thus, highways with an average of 6,000 vehicles per day on an annual basis carried over 12,000 vehicles on 3 days, over 11,000 vehicles on 11 days, over 8,000 vehicles on 50 days, etc. The curves shown on the figure indicate that for the average location, the 24-hour traffic volume that is exceeded any certain number of days is nearly proportional to the annual average 24-hour traffic volume.

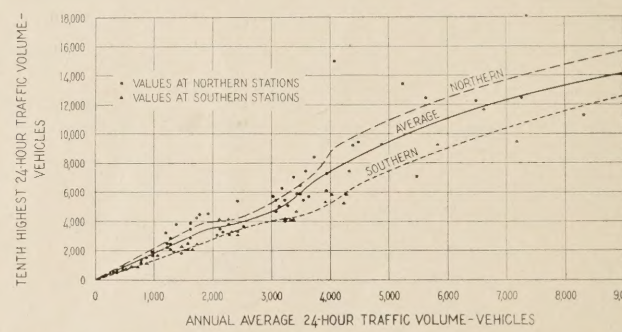

FIGURE 5.—TENTH HIGHEST 24-HOUR TRAFFIC VOLUME DURING 1 YEAR FOR VARIOUS ANNUAL AVERAGE 24-HOUR TRAFFIC VOLUMES.

LARGE PROPORTION OF TRAFFIC MOVES DURING PEAK HOURS

Thus, the average highway carrying 4,000 vehicles a day has approximately the same number of days per year with a traffic volume in excess of 5,000 vehicles as a highway carrying 8,000 vehicles per day has days when traffic exceeds 10,000 vehicles. The curves show 56 days in the one case and 47 days in the other.

Since for all roads there is a large variation in the traffic volumes for different hours of the day, and since

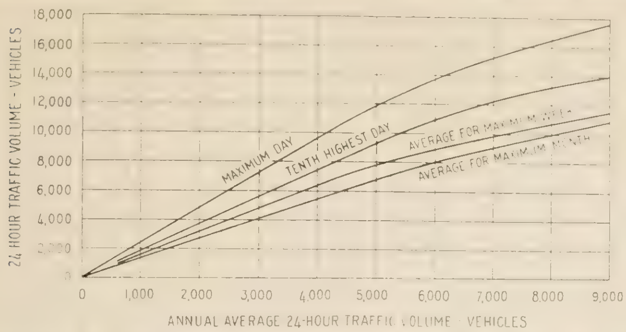

FIGURE 6.—RELATION BETWEEN VARIOUS 24-HOUR TRAFFIC VOLUMES DURING YEAR AND AVERAGE 24-HOUR TRAFFIC VOLUME. (DETERMINED FROM DATA FOR 89 HIGHWAY LOCATIONS.)

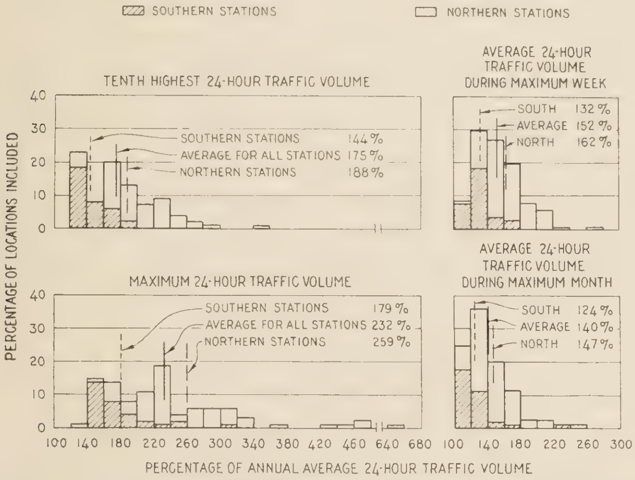

FIGURE 7.—VARIATION IN RELATION BETWEEN 24-HOUR TRAFFIC VOLUMES DURING PEAK TRAFFIC DENSITY PERIODS AND ANNUAL AVERAGE 24-HOUR TRAFFIC VOLUMES AT DIFFERENT LOCATIONS.

the hourly rather than the daily volume is the more practical unit to use as a basis for measuring the capacity of a highway and for design purposes, a number of figures showing the relations between the annual average 24-hour volumes and the individual hourly volumes are presented.

Figure 9 shows the relations between the maximum hour during a year and the average 24-hour volume at each location. The range in maximum hours for stations having similar yearly traffic volumes is great. There are cases in which the maximum for one highway is nearly six times as great as the maximum for another highway carrying the same total number of vehicles during a year. Even the fiftieth highest hour as shown by figure 10 is sometimes three times as high for one station as for another station with the same annual traffic.

The slopes of curves for the relations between the maximum and fiftieth highest hours and the annual 24-hour averages also have a tendency to decrease when the annual average reaches about 2,000 vehicles and then to increase until they return almost to their former slopes near 4,000 vehicles per hour. The curves for the stations located in northern States are considerably higher than those for the stations in southern States.

Figure 11 shows the relations between the maximum hour, the tenth, thirtieth, and fiftieth highest hours, and the average daily volume during the year. The curves shown in this figure have been smoothed to eliminate the sags at annual volumes between 2,000 and 4,000 vehicles which were probably caused by conges-

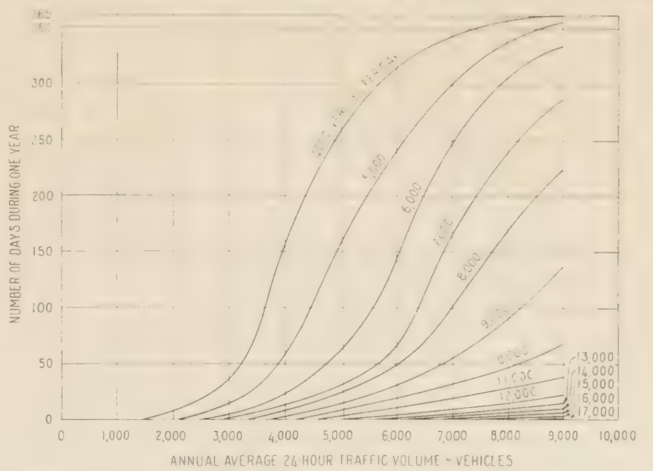

FIGURE 8.—NUMBER OF DAYS DURING 1 YEAR THAT VARIOUS 24-HOUR TRAFFIC VOLUMES WERE EXCEEDED. (DETERMINED FROM DATA FOR 89 HIGHWAY LOCATIONS.)

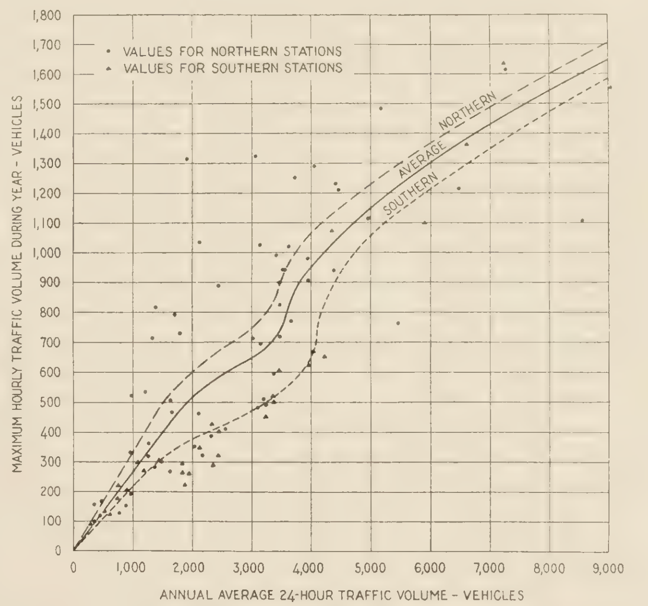

FIGURE 9.—RELATION BETWEEN MAXIMUM HOURLY TRAFFIC VOLUME DURING YEAR AND ANNUAL AVERAGE 24-HOUR TRAFFIC VOLUME.

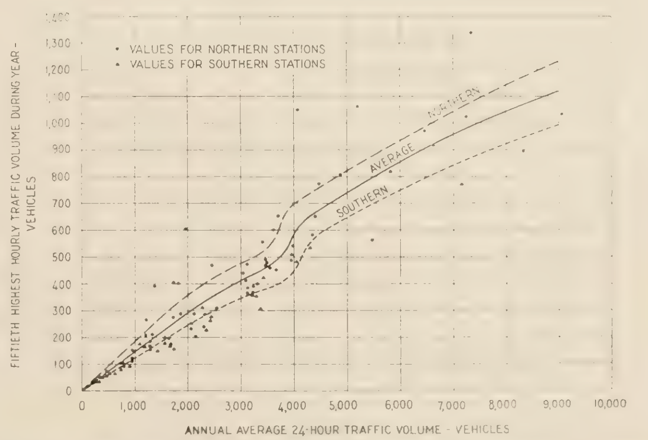

FIGURE 10.—RELATION BETWEEN FIFTIETH HIGHEST HOURLY TRAFFIC VOLUME AND ANNUAL AVERAGE 24-HOUR TRAFFIC VOLUME.

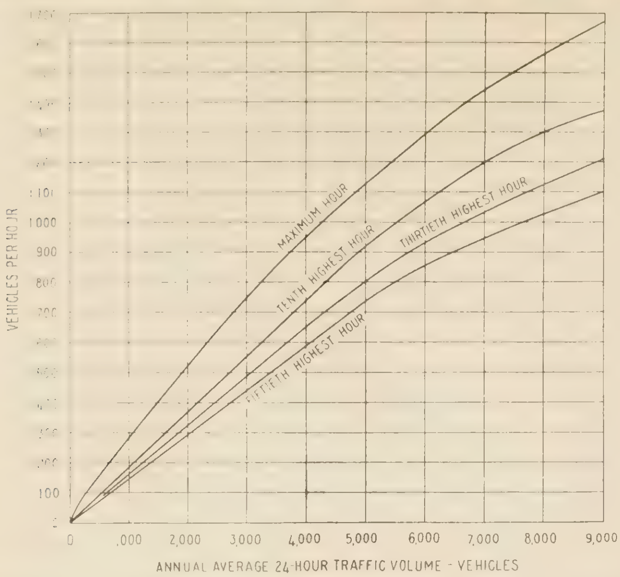

Figure 11.—Relation Between Various Hourly Traffic Volumes During Year and Annual Average 24-Hour Traffic Volumes. (Determined From Data for 89 Highway Locations.)

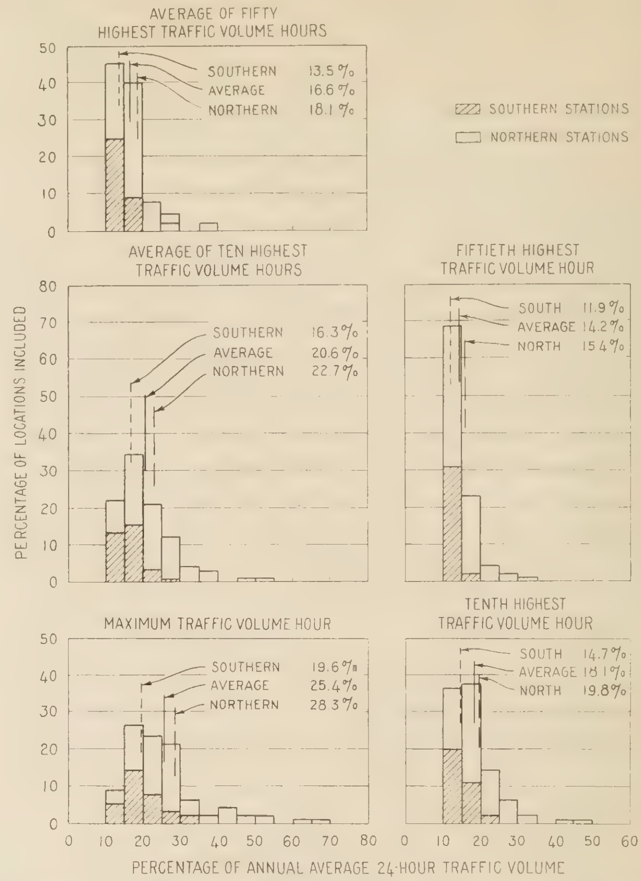

Figure 12.—Variation in Relation Between Hourly Traffic Volumes During Peak Hourly Traffic Density Periods and Annual Average 24-Hour Traffic Volumes at Different Locations.

tion on some of the 2-lane roads in this group during peak hours.

The variations in the percentages that the peak hourly volumes are of the annual average 24-hour volumes for different locations are shown by figure 12. It may be seen from this figure that the variation between locations decreases as the number of peak hours that are included increases. Thus, although the maximum hours average 25.4 percent of the average daily volume, at only 23.5 percent of the locations is the maximum between 20 and 25 percent of the annual average. For 69 percent of the locations the fiftieth highest hour falls within the same 5-percent range group as the average for all of the fiftieth highest hours. As with the daily volumes, the peak hourly volumes for the northern locations cover a wider range and are a larger percentage of the annual average 24-hour density than corresponding peaks for southern locations.

Data were available for the percentages that out-of-State and commercial vehicles were of the total traffic for 70 of the 90 locations studied. There did not seem to be any relationship between the percentage of out-of-State vehicles and the traffic volume fluctuation but, on an average, there was a slight decrease in the fluctuation with an increase in the percentage of trucks (table 3). Since in the automatic counter records there is no separation of trucks from passenger cars, it was not possible to determine the cause of this decrease. It is reasonable to assume that the peak truck densities occur at different times, either seasonal, daily, or hourly, than the peak passenger-car densities. Furthermore, routes of heavy truck traffic are usually those between centers of population between which also flows a substantial volume of passenger cars used on weekdays for business purposes. Both of these factors tend to increase the weekday volume in comparison to the Sunday flow.

Table 4 shows the relation between the number of vehicles during peak traffic density periods and the annual average 24-hour traffic volume. On an average, there is a very rapid decrease in the average hourly volume during the peak period as the number of hours included in the peak period is increased. When the 50 hours of peak traffic density, which cover only 0.57 percent of the total time, are included, the average hourly volume is only 16.6 percent of the annual 24-hour average whereas the maximum hour is 25.4 percent of the annual 24-hour average. The percentage of total vehicles included in the peak hours is always relatively large as compared to the percentage of time involved.

Table 3.—*Effect that the percentage of trucks has on the relation between the traffic volume during peak density periods and the annual average 24-hour volume*

Percentage of trucks included in total traffic		Number of locations	Percentage of annual average 24-hour traffic volume		
Group limits	Average		Maximum hour during year	Tenth highest hour during year	Fiftieth highest hour during year
Below 15	10.9	9	27.7	21.2	15.9
15–20	17.4	19	26.2	18.4	14.6
20–25	22.6	22	26.4	18.2	14.2
Above 25	27.6	20	23.2	17.3	13.6

DATA ON TRAFFIC VOLUMES DURING PEAK HOURS NEEDED FOR DESIGN OF HIGHWAYS

Figure 13 shows the average number of hours each year that the traffic density exceeded various hourly traffic volumes for highways with different annual average 24-hour volumes. Thus, highways carrying an annual average of 5,000 vehicles per day had 610 hours when the traffic volume exceeded 400 vehicles per hour, 350 hours when the traffic volume exceeded 500 vehicles per hour, 200 hours when the traffic volume exceeded 600 vehicles per hour, etc.

It is a generally accepted fact that it is not economically advisable to construct a highway to accommodate the peak traffic densities that will use it during its probable life, unless to do so involves no additional construction cost over designs to accommodate fewer vehicles. However, the time, percentage of time, number of vehicles, or percentage of vehicles that may be included in the peak traffic densities not cared for by the design are still unknown quantities. Although the design will depend to a large extent upon the funds available for construction, figure 13 throws some light on the hourly traffic volumes for which highways with different annual traffic densities and having average traffic fluctuations should be designed. From the figure, it may be seen that for any annual average 24-hour traffic volume, there is a rapid increase in the number of hours included between each 100-vehicle change in the hourly volume when the number of hours included is greater than the 50 peak hours, but there is only a small change in the number of hours included as the volume goes below the value shown for the thirtieth highest hour.

TABLE 4.—*Relation between number of vehicles during peak traffic density periods and the annual average 24-hour traffic volume (average for 60 northern and 30 southern stations)*

Time period	Percent that average hourly traffic volume during peak density periods is of annual average 24-hour traffic volume			Percentage of total time included (annual basis)	Percentage of total annual traffic included		
	Northern stations	Southern stations	All stations		Northern stations	Southern stations	All stations
Maximum month (30 days)	6.1	5.2	5.8	8.21	12.03	10.26	11.44
Maximum week	6.8	5.5	6.3	1.92	3.13	2.53	2.90
10 highest days	8.9	6.4	8.1	2.74	5.85	4.21	5.33
Maximum day	10.8	7.4	9.7	.27	.71	.49	.64
Maximum hour	28.3	19.6	25.4	.01	.08	.05	.07
10 highest hours	22.7	16.3	20.6	.11	.62	.45	.56
20 highest hours	20.9	15.0	19.5	.23	1.15	.82	1.07
30 highest hours	19.6	14.3	18.2	.34	1.61	1.18	1.50
40 highest hours	18.8	13.9	17.4	.46	2.06	1.52	1.91
50 highest hours	18.1	13.5	16.6	.57	2.48	1.85	2.30

For example, at the average location with an annual average 24-hour traffic volume of 4,000 vehicles, the various hourly traffic volumes are exceeded for the number of hours shown in the following tabulation:

Hourly traffic volume:	*Number of hours during 1 year*
950	1
800	8
700	20
650	30
600	50
500	115
400	280

A design based on the maximum hourly volume would be required to handle nearly 1½ times as many vehicles per hour as a design based on the 30 peak traffic volume hours, but the additional number of vehicles accommodated would only be 1.5 percent of the annual traffic (table 4). On the other hand, designing for a traffic volume only 30 percent less than the volume exceeded during 50 hours would result in a 560 percent increase in the number of hours of traffic not accommodated by the design. The percentage of the total number of

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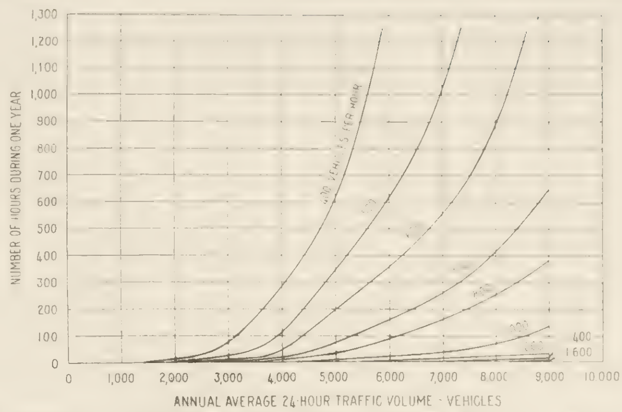

FIGURE 13.—NUMBER OF HOURS THAT VARIOUS HOURLY TRAFFIC VOLUMES ARE EXCEEDED ON HIGHWAYS HAVING DIFFERENT ANNUAL TRAFFIC DENSITIES. (DETERMINED FROM DATA FOR 89 HIGHWAY LOCATIONS.)

vehicles using the highway that would not be accommodated by the design would be increased from 2.3 to 9.9. It, therefore, seems that for the average highway, it is impractical to design for a greater hourly volume than the value which will be exceeded only during the 30 peak hours each year and that little will probably be saved in the construction cost and a great deal lost in expediting the movement of traffic if a design is used that will not handle the traffic volume exceeded during the 50 peak hours. The exact value to use depends upon the traffic volumes that the different designs will accommodate. Thus, if the traffic volume is such that to accommodate the hourly volume exceeded for 30 hours during a year requires a greater number of traffic lanes than to accommodate the hourly volume exceeded for 50 hours, the lower number of lanes should probably be used.

Since this analysis is based on the average fluctuation in traffic density for many highways, the results are not applicable to each location. For an extreme example, a comparison has been made of the data for the station included in this anlaysis that had the greatest fluctuation in the hourly traffic volumes during the year and the station that was found to have the most uniform flow of traffic. The percentage of the total time during which each of these road sections carried traffic volumes in excess of different numbers of vehicles per hour and the percentage of all vehicles that passed over each road section when the hourly traffic volume was in excess of the specified traffic densities are shown by table 5. The section with the largest variation in traffic flow had an annual average 24-hour traffic volume of 4,057 vehicles, was located in the North, and is referred to as section A. The one with the most uniform traffic flow had an annual average 24-hour traffic volume of 4,226 vehicles, was located in the South, and is referred to as section B.

Although practically the same number of vehicles used these two road sections in 1 year, the traffic on section B was rarely in excess of 500 vehicles per hour, while on section A it sometimes reached 1,200 vehicles per hour and was in excess of 500 vehicles per hour for 5.5 percent of the time. Since the percentage of the total vehicles during high density periods is greater than the percentage of the total time occupied by the same density periods, 25.1 percent of the vehicles traveled over section A during the 5.5 percent of the time that the hourly density exceeded 500 vehicles.

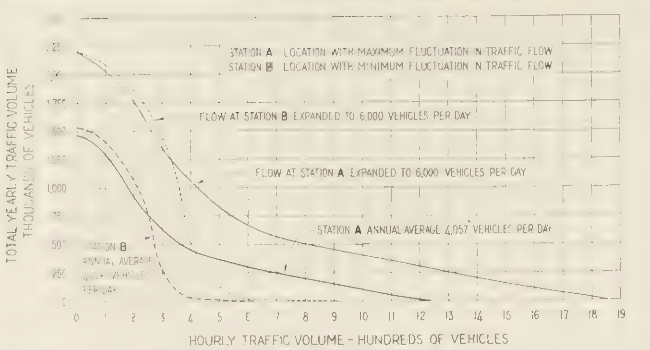

FIGURE 14.—CUMULATIVE FREQUENCY CURVES SHOWING THE NUMBER OF VEHICLES WHEN TRAFFIC IS IN EXCESS OF VARIOUS HOURLY TRAFFIC VOLUMES AT STATIONS HAVING MAXIMUM AND MINIMUM FLUCTUATION IN TRAFFIC FLOW.

TABLE 5.—*Percentage of time and percentage of vehicles included during periods that road sections carried traffic in excess of different hourly volumes*

Hourly volume, vehicles	Cumulative percentage of total time		Cumulative percentage of total vehicles	
	Section A	Section B	Section A	Section B
1,200	0.2		1.3	
1,100	.5		3.3	
1,000	1.1		6.8	
900	1.6		9.9	
800	2.3		13.3	
700	3.0		16.4	
600	4.2	(1)	20.8	0.1
500	5.5	0.1	25.1	.2
400	7.6	.9	30.3	2.3
300	14.0	9.0	43.2	18.0
200	26.7	46.5	61.2	70.2
100	57.6	71.6	87.5	91.0
0	100.0	100.0	100.0	100.0

[1] Less than 0.1 percent.

Figure 14 shows the data obtained from the automatic traffic recorders located at these 2 stations in a most useful form. The curve for traffic at station B shows that a highway designed to accommodate 400 vehicles per hour would be the most economical design at this location for the present traffic, since designing for a greater volume would result in but a slight increase in the number of vehicles accommodated, and designing for a traffic volume even slightly less than 400 vehicles per hour would result in a relatively large increase in the number of vehicles that would be required to use the highway during periods when the volume was in excess of the design value.

RECORDS OF PAST YEARS USEFUL IN ESTIMATING FUTURE PEAK TRAFFIC VOLUMES

Highway design for the traffic flow at station A presents a more difficult problem. Based only on the annual traffic density, the same design could be used at both locations; but if the design at station A were based on 400 vehicles per hour, nearly half a million, or one-third of the vehicles, would use the road during periods when the traffic density exceeded the design value. A design to accommodate the same percentage of vehicles at station A as are accommodated by a design of 400 vehicles per hour at station B would have to accommodate 1,200 vehicles per hour. The actual design value for the location represented by station A would depend entirely upon the funds available and the hourly capacity of highways of different designs. However, if the present width of surface and alinement were identical at these two locations, the highway with the traffic flow represented by station A

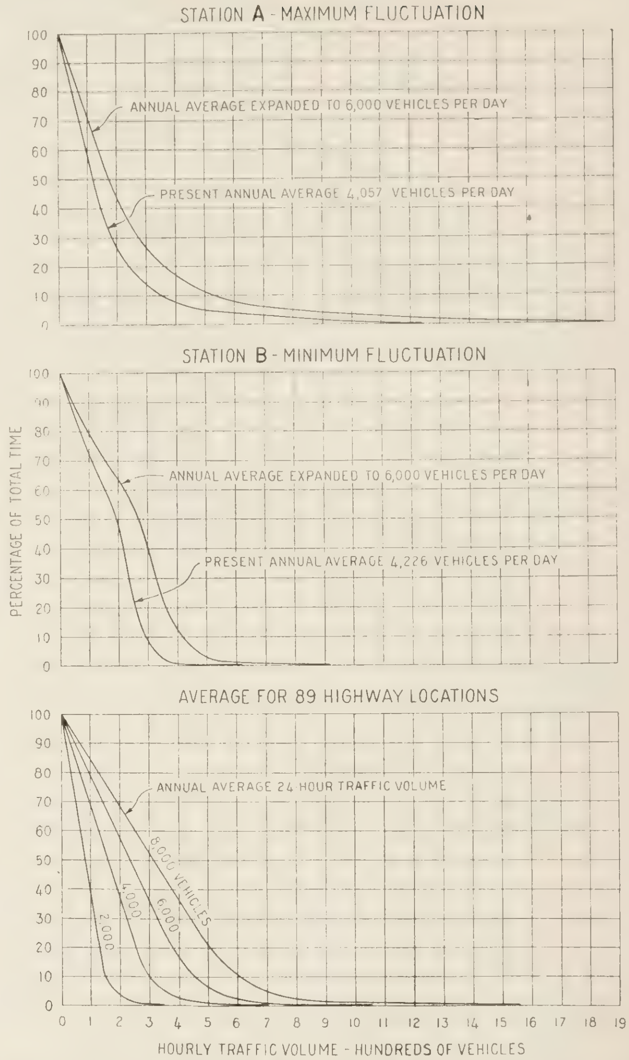

FIGURE 15.—CUMULATIVE FREQUENCY CURVES SHOWING THE PERCENTAGE OF TIME THAT THE TRAFFIC WAS IN EXCESS OF VARIOUS HOURLY VOLUMES ON HIGHWAYS HAVING THE MAXIMUM, MINIMUM, AND AVERAGE FLUCTUATION IN THE FLOW OF TRAFFIC.

should be given prior consideration in any construction or improvement program designed to reduce traffic congestion such as the elimination of short sight distances, increasing the surface width, increasing the number of traffic lanes, or providing grade separations.

Since highway construction programs must be based on future as well as present traffic densities to avoid obsolescence in a relatively short time, it is essential to estimate future fluctuations in the traffic volumes as well as the future increase in the annual traffic. A study of the future variation in traffic flow can usually be based on the present fluctuation. When a cumulative frequency curve such as the one shown in figure 14 has been determined, it will generally be safe to assume that the shape of the curve will not change materially with either an increase or decrease of average daily traffic unless it is definitely known that some local development will tend to alter the shape of the curve.

If it is assumed that an increase in the annual traffic affects all portions of present traffic volumes proportionally and that the annual average daily traffic will increase to 6,000 vehicles at some future date, the

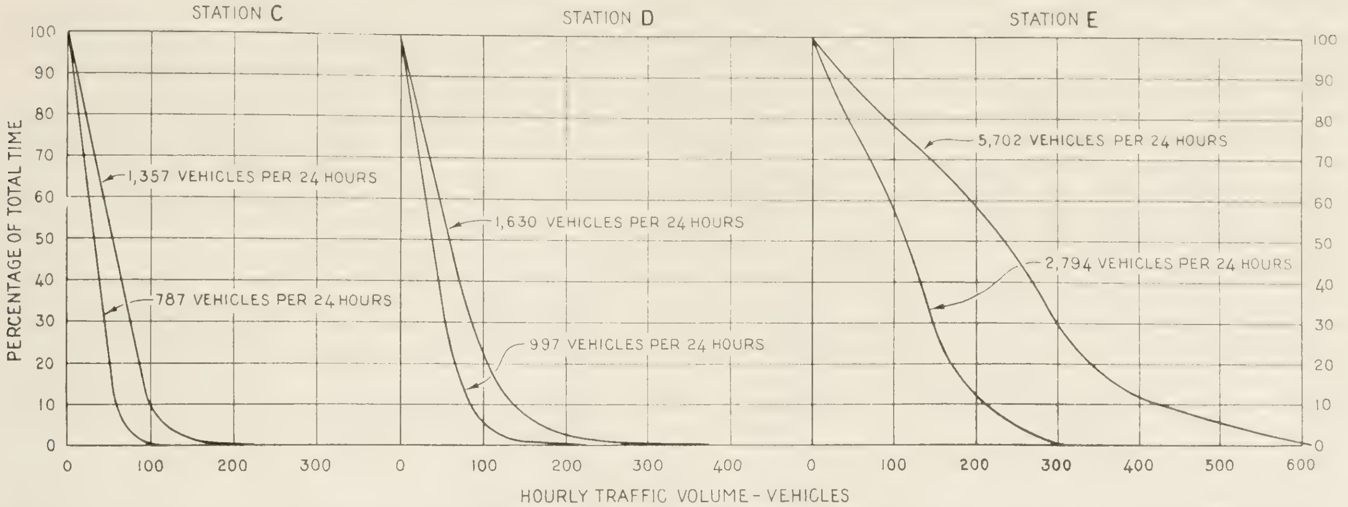

Figure 16.—Percentage of Time That Traffic Was in Excess of Various Hourly Densities at Stations Where There Was an Appreciable Difference in the Average 24-Hour Volumes for the Same Period in Successive Years.

cumulative frequency curves as obtained from the present records made by the automatic recorders can be expanded by increasing both values for points along the present traffic curve in the same ratio as the estimated future annual traffic is to the present traffic. By expanding the curves for the present traffic on sections A and B in this manner to annual average daily volumes of 6,000 vehicles, the expanded cumulative frequency curves as shown by the light lines on figure 14 were obtained. In a similar manner, the data for the present traffic can be expanded to any annual average daily volumes. It is interesting to note that at the present time, with a volume of 4,057 vehicles per day, a larger number of vehicles travel over the highway represented by station A during periods when the traffic volume exceeds any value over 420 vehicles per hour, than will travel over the highway represented by station B when the annual average daily volume reaches 6,000 vehicles.

Since the curves shown in figure 14 represent locations with the maximum and minimum fluctuation in traffic flow found by analyzing records at 90 stations located on U. S. routes in all parts of the country, it is reasonable to expect that similar curves for practically all sections on U. S. numbered highways will fall somewhere between the curves representing these two locations for corresponding annual traffic volumes. However, the range between the two curves for identical traffic volumes is so great that they emphasize the importance of having at least a full year's record from an automatic traffic recorder before an intelligent analysis can be made of the traffic needs on any particular section of highway where improvements to increase the traffic capacity of the highway are contemplated.

Cumulative frequency curves of the type shown in figure 15 are useful when it is desired to compare the percentage of time that traffic on different road sections is in excess of various hourly volumes. The data obtained from the automatic traffic counters at the stations included in this analysis where the maximum and minimum fluctuation in traffic flow were recorded, have been used in plotting the curves for stations A and B, respectively. When expanding the data shown by the original curves to other traffic volumes, the values along the abscissa are increased by the same ratio as the annual traffic, while the values along the ordinate are held constant. The values for stations A and B have been expanded to show the percentage of time that the traffic will be in excess of various hourly volumes when the annual average volume increases to 6,000 vehicles per day (fig. 15). In a similar manner, the data for 89 locations were expanded to annual 24-hour traffic volumes of 6,000 vehicles and the values averaged to obtain the average cumulative frequency curve shown in figure 15. This curve and other curves formed by expanding the individual values to other traffic densities show the relation between time and hourly traffic density for highways with the average fluctuation in traffic flow.

The method outlined above for estimating the percentage of time, number of vehicles, or number of hours included in the various hourly traffic density groups when there is a change in the annual traffic, assumes that the change will affect all portions of the cumulative frequency curves proportionately. This will always be true when all portions of the traffic pattern are affected proportionately but may also be true even though there is a material change in the traffic pattern.

Since automatic, hourly recording counters have only been in operation during recent years, there were only three stations where the recorders had been operated continuously for at least 2 years and where there had been sufficient increases in the annual traffic densities during the period of operation to check the accuracy of this assumption. At these three locations, referred to as stations C, D, and E, the total traffic volumes during the same period in successive years had increased from averages of 787, 997, and 2,794 vehicles per day to 1,357, 1,630, and 5,702 vehicles per day, respectively. The cumulative curves for the percentage of time that traffic at the 3 stations was in excess of various hourly volumes during each of the 2 different traffic density periods are shown by figure 16. In each case, if the values shown for the lower volume curve are expanded in the same ratio as the two average 24-hour volumes are to each other, as previously outlined, the curves for the higher average volumes will be exactly duplicated.

While such a close agreement will probably not be found for all locations, especially where local developments tend to influence the traffic pattern and where the increase takes place over a period of 10 or 20 years, the data available at the present time substantiate the

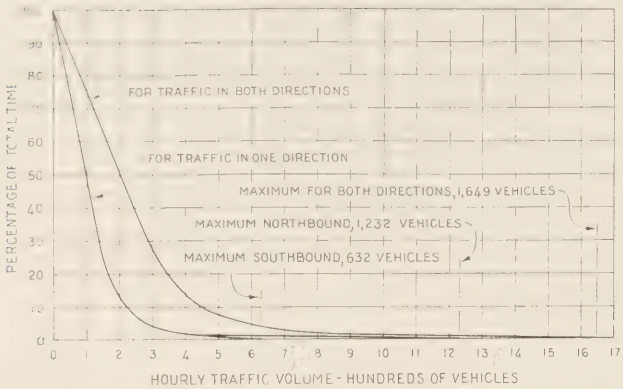

FIGURE 17.—PERCENTAGE OF TIME THAT TRAFFIC DENSITY ON U. S. ROUTE 41 WAS IN EXCESS OF VARIOUS HOURLY VOLUMES. (ANNUAL AVERAGE 24-HOUR TRAFFIC VOLUME WAS 5,614 VEHICLES.)

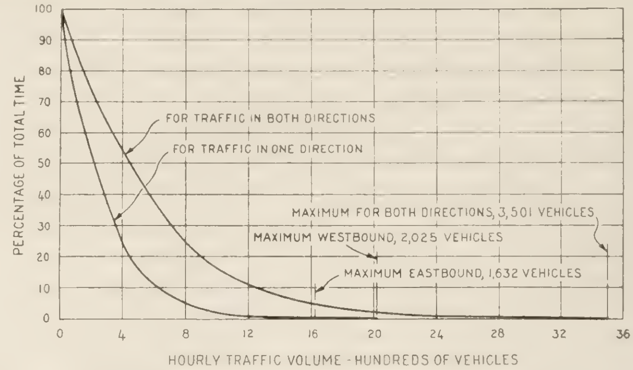

FIGURE 18.—PERCENTAGE OF TIME THAT TRAFFIC DENSITY ON THE MERRITT PARKWAY WAS IN EXCESS OF VARIOUS HOURLY VOLUMES. (ANNUAL AVERAGE 24-HOUR TRAFFIC VOLUME WAS 13,624 VEHICLES.)

one assumption necessary to expand the automatic recorder data to care for increased annual traffic densities.

PERCENTAGE OF TRAFFIC MOVING IN EACH DIRECTION DURING PEAK HOURS IMPORTANT

For design and traffic control purposes it is often desirable to know the percentage of the total vehicles traveling in each direction during hours of high traffic density. This can be obtained for divided highways by using an automatic traffic recorder for each of the two directions. On undivided roadways, the automatic recorders using either light beams or the direct contact or pneumatic tube as the means of detection can be equipped with special units so that only vehicles traveling in one direction will be recorded. Approximate values can also be obtained when the contact type of detector is used by placing the detector so that only vehicles traveling on one-half of the roadway will be recorded. By proper selection of locations, the error due to vehicles traveling to the left of the center of the roadway, as when passing, can be reduced to a minimum.

Cumulative frequency curves for two locations on divided highways, where automatic traffic counters obtained the number of vehicles in each direction for each hour during periods exceeding 1 year, are shown by figures 17 and 18.

The percentage of time that the traffic at automatic recorder stations 2 and 3 on U. S. Route 41, 18 miles south of Milwaukee, Wisconsin, was in excess of various hourly volumes is shown by figure 17. At station 2 south-bound traffic was recorded, while at station 3 north-bound traffic was recorded. By adding the number of vehicles in the two directions for corresponding hours, the total traffic on the route during each hour of the year was obtained. Although the number of vehicles traveling in each of the two directions was rarely the same for any particular hour, the number of hours that each direction carried the various traffic volumes below 300 vehicles per hour was approximately equal to the number of hours during a year that the total traffic volume in both directions was twice the corresponding densities. Both directions carried traffic volumes in excess of 300 vehicles per hour for 4 percent of the time, and the total volume was in excess of 600 vehicles per hour for 4 percent of the time. The maximum volume of south-bound traffic was 632 vehicles per hour and the maximum volume of north-bound traffic was 1,232 vehicles per hour, but the total volume never exceeded 1,649 vehicles per hour. During the 1 hour that the total volume reached 1,649 vehicles, 74.7 percent of the traffic was in one direction. During the 10 peak hours of total traffic volume, the traffic in one direction averaged 70 percent of the total traffic.

On the Merritt Parkway, at traffic recorder stations 6 and 7 near Greenwich, Conn., the traffic in one direction exceeded all traffic volumes below 1,100 vehicles per hour for the same number of hours that the total volume exceeded twice the corresponding densities (fig. 18). East-bound, west-bound, and total traffic never exceeded 1,632, 2,025, and 3,501 vehicles per hour, respectively. During the 10 peak hours, the traffic in one direction averaged 57 percent of the total traffic.

The results obtained at these two locations indicate that if a cumulative frequency curve of the type shown in figures 17 and 18 is available for either the traffic in one direction or for the total traffic, the curves for both the traffic in one direction and the total traffic can be obtained, except for a very small portion of the total time when the peak volumes occur. It is also evident that unless practically all the vehicles are to be accommodated, designs for each direction of traffic based on half of the total volume are sufficient, but if all vehicles are to be accommodated, the design for each direction must in some cases be based on volumes as high as 70 percent of the peak total volumes.

COMPLETE TRAFFIC RECORDS USEFUL IN SELECTING SCHEDULES FOR TRAFFIC SURVEYS

The second of the general problems for which automatic traffic recorder data furnish a means of attack is that of planning observation schedules for traffic surveys. A satisfactory schedule must require sufficient observation in the field to enable an accurate estimate of the year's total traffic and of the various types of vehicle units of which it is composed. Results of the schedule operation should enable the analyst to make estimates of the ranges in traffic volume—in particular an estimate of traffic during periods of maximum volume.

The schedule should be so devised as to balance cost of operation against accuracy of results; i. e., the time for which it is necessary to pay men to count traffic should be as small as possible so that costs will be low, while the time for which traffic must be observed must be as large as is necessary to assure accurate results.

It has been recognized in earlier analyses [3] that traffic volume is affected principally by the hour, day of the week, and the month in which the count is taken. Less predictable effects upon traffic volume result from variation in weather conditions, detoured traffic from a normal route due to road construction or other reasons, holidays, football games, fairs, or other events attracting unusual numbers of people.

There are, of course, a number of means by which allowance may be made in the schedule of operation to provide measures of the hourly, daily, and seasonal fluctuations in traffic. Because of the numerous possibilities, it is feasible to test but a few of these possible schedules. Since total traffic has been measured by the automatic traffic recorders, the average daily traffic may be computed with precision; and since data are available for every hour and every day of the year at a large number of locations, any combination of hours, days, and seasons may be selected. From the selected periods or assumed schedule, an estimated average daily traffic may be computed. Comparison of the estimated values under various assumed schedules with exact values obtained from the year's complete record will establish the relative accuracy of the various schedules selected for test.

One of the schedules selected for test is the "key station schedule" first used [4] in the Western States Traffic Survey and in subsequent surveys in which the Public Roads Administration cooperated, and by the various States in the Highway Planning Surveys.

> Each operation covered a 10-hour period on a staggered schedule from 6 a. m. to 4 p. m. and from 10 a. m. to 8 p. m. with splits in the count at 10 a. m. and 4 p. m. This permitted a continuation series of the 10 a. m. to 4 p. m. section through all operations, which were scheduled to provide two counts for each of the 7 days of the week. Sufficient night counts from 10 p. m. to 6 a. m. were obtained to adjust all data to a 24-hour day.[5]

When the 8-hour counting period became generally used, this schedule was modified to cover the 6 a. m. to 2 p. m. and 2 p. m. to 10 p. m. periods alternately at intervals of 26 days, thus covering each day of the week at 6-month intervals (schedule I). Sufficient night counts, usually four in number, were seasonally spaced to cover the 10 p. m. to 6 a. m. period. The effects of the schedule were: To balance the seasonal variation in traffic; to cover the full 24 hours at each point of observation; to cover each of the days of the week at every point; and to set up the operation in such a manner as to keep a relatively small force of men continuously employed, with days of no work equivalent to those received by men in other forms of employment.

The second schedule (schedule II) to be tested is that recommended at the location of the recording type automatic traffic counters in the continuing traffic surveys conducted as an integral feature of the Highway Planning Surveys. Machines are operated for a 24-hour period on Saturday and Sunday and either on Friday or Monday to give a continuous record of the three typical days of the statistical week. These stations may be considered as control stations of the continuing blanket counts.

The third schedule (schedule III) to be tested with the data available from the automatic traffic recorders is one in which it is assumed that each period of observation is but 1 hour in duration. There are a total of 40 such observation periods at each station, scattered throughout the year as indicated in the following sample schedule:

a. m.		*p. m.*	
12– 1	Apr. 7	12– 1	Mar. 14 Sept. 22
1– 2	May 25	1– 2	Mar. 26 (Sunday) Oct. 4
2– 3	July 12	2– 3	Apr. 7 Oct. 16
3– 4	Aug. 29	3– 4	Apr. 19 Oct. 28 (Saturday)
4– 5	Oct. 16	4– 5	May 1 Nov. 9
5– 6	Dec. 3	5– 6	May 13 (Saturday) Nov. 21
6– 7	Jan. 1 (Sunday) July 12	6– 7	May 25 Dec. 3 (Sunday)
7– 8	Jan. 13 July 24	7– 8	June 6 Dec. 15
8– 9	Jan. 25 Aug. 5 (Saturday)	8– 9	June 18 (Sunday) Dec. 27
9–10	Feb. 6 Aug. 17	9–10	June 30 Jan. 7 (Saturday)
10–11	Feb. 18 (Saturday) Aug. 29	10–11	Jan. 1
11–12	Mar 2 Sept. 10 (Sunday)	11–12	Feb. 18

It will be noted that under this schedule of operation the period from 6 a. m. to 7 a. m. is covered in January and in July, at nearly 6-month intervals. The 7 a. m. to 8 a. m. hour is also covered in January and July, again approximately at 6-month intervals, and so for all of the hours from 6 a. m. to 10 p. m. The remaining hours, those normally of much lesser traffic importance, are covered but once, at approximately 6-week intervals throughout the year.

ACCURACY OF THREE OBSERVATION SCHEDULES DETERMINED

The estimates of average daily traffic under each assumed schedule are computed as follows: At the key stations (schedule I), traffic observed during the 6 a. m. to 2 p. m., 2 p. m. to 10 p. m., and 10 p. m. to 6 a. m. periods is averaged and the three averages are totaled for the estimated average daily traffic. At the control blanket-count stations (schedule II), the observed weekday traffic is multiplied by 5, traffic counts for a Saturday and a Sunday are added, and the total is divided by 7 for the counts taken during each season. The 4 seasonal averages, thus computed, are totaled and divided by 4 to give the estimated average daily traffic for the year. At the stations where traffic is assumed to have been observed only during hourly periods (schedule III) the averages of the 2 observations for each hour from 6 a. m. to 10 p. m. are obtained. To these averages (16 in number) are added the observed traffic for each hour from 10 p. m. to 6 a. m. The result is the estimated average daily traffic under this schedule.

Tables 6, 7, and 8 present the average daily traffic computed from schedules I, II, and III, using the analysis methods outlined above. In table 6 the stations were those located on State routes that carried a relatively large volume of traffic. In table 7, stations were also those located on State routes, but with a light traffic volume; while in table 8 all stations were on local routes, usually those carrying a smaller traffic volume than the stations used in table 7. Thirty-three stations were included in each of the above classes.

In addition to the computed averages, the true average daily traffic and the ratios of the various computed averages to the true averages, are tabulated. Weighted averages of these ratios are shown in the last line of each table.

[3] Highway Traffic Analysis Methods and Results, by L. E. Peabody. PUBLIC ROADS, vol. 10, No. 1, March 1929.
[4] The Western States Traffic Survey, by L. E. Peabody. PUBLIC ROADS, vol. 13, No. 1, March 1932.
[5] Digest of Report on Arkansas Traffic Survey, by L. E. Peabody. PUBLIC ROADS, vol. 17, No. 6, August 1936.

TABLE 6.—*Automatic traffic recorder averages for year 1939, State routes carrying heavy traffic*

State	Station	Average daily traffic: Schedule I	Schedule II	Schedule III	Actual average for year	Percentage of actual average: I	II	III
Massachusetts	1	2,926	3,413	3,066	2,959	98.9	115.3	103.6
Pennsylvania	22	6,635	7,462	7,062	7,069	93.9	105.6	99.9
Connecticut	2	3,811	4,127	3,755	[1] 3,915	97.3	105.4	95.9
	17	7,993	8,974	8,444	[2] 8,112	98.5	110.6	104.1
Florida	10	3,500	4,356	3,576	3,462	101.1	125.8	103.3
	13	1,748	1,934	1,924	1,805	96.8	107.1	106.6
Michigan	676	3,241	3,926	3,430	3,460	93.7	113.5	99.1
Louisiana	14	2,999	2,977	2,974	3,046	98.5	97.7	97.6
Missouri	9	5,131	5,372	5,278	5,266	97.4	102.0	100.2
Texas	1	8,774	9,130	9,323	9,102	96.4	100.3	102.4
Colorado	11	5,480	5,507	6,010	[3] 5,578	98.2	98.7	107.7
Washington	10	3,270	3,521	3,418	3,427	95.4	102.7	99.7
Oregon	2	1,012	990	989	985	102.7	100.5	100.4
California	1	6,091	6,185	6,452	6,316	96.4	97.9	102.2
	10	4,105	4,464	4,383	4,159	98.7	107.3	105.4
Alabama	5	5,300	5,390	5,755	5,381	98.5	100.2	107.0
	7	1,488	1,592	1,547	1,612	92.3	98.8	96.0
Arizona	1	7,115	7,528	7,592	7,210	98.7	104.4	105.3
	3	1,873	1,967	2,003	[4] 1,889	99.2	104.1	106.0
Arkansas	13	2,191	2,118	2,186	[5] 2,169	101.0	97.6	100.8
	14	2,480	2,540	2,382	[5] 2,542	97.6	99.9	93.7
California	6	2,892	2,652	2,442	[6] 2,637	109.7	100.6	92.6
	2	2,526	2,464	2,465	[6] 2,521	100.2	97.7	97.8
	9	4,015	4,073	3,805	[7] 4,141	97.0	98.4	91.9
Connecticut	12	4,883	5,218	4,809	[4] 5,085	96.0	102.6	94.6
	15	9,015	9,363	9,696	[1] 9,367	96.2	99.9	103.5
Georgia	1	3,249	3,166	3,155	3,238	100.3	97.8	97.4
	3	4,347	4,430	4,260	4,363	99.6	101.5	97.6
Idaho	2	2,677	2,742	2,820	2,724	98.3	100.7	103.5
	3	2,436	2,438	2,430	2,468	98.7	98.8	98.5
Illinois	9	4,314	4,586	4,273	4,465	96.6	102.7	95.7
Indiana	59A	3,179	3,664	3,295	3,407	93.3	107.5	96.7
Iowa	601	3,219	3,774	3,437	[8] 3,444	93.5	109.6	99.8
Weighted average						97.5	103.4	100.8
Weighted percentage of error						3.01	4.28	3.59

[1] Feb. 18, 1939–Feb. 17, 1940.
[2] Feb. 25, 1939–Feb. 24, 1940.
[3] Dec. 17, 1938–Dec. 16, 1939.
[4] Mar. 10, 1939–Mar. 9, 1940.
[5] Jan. 29, 1939–Jan. 28, 1940.
[6] Year 1938.
[7] Feb. 5, 1937–Feb. 4, 1938.
[8] Apr. 16, 1938–Apr. 15, 1939.

TABLE 7.—*Automatic traffic recorder averages for year 1939, State routes carrying light traffic*

State	Station	Average daily traffic: Schedule I	Schedule II	Schedule III	Actual average for year	Percentage of actual average: I	II	III
Arizona	5	201	206	193	206	97.6	100.0	93.7
Arkansas	7	194	209	207	198	98.0	105.6	104.5
Georgia	11	280	295	299	292	95.9	101.0	102.4
Iowa	607	435	455	448	434	100.2	104.8	103.2
Louisiana	13	151	149	153	[1] 150	100.7	99.3	102.0
Minnesota	171	263	268	271	[2] 275	95.6	97.5	98.5
	174	283	293	332	[3] 298	95.0	98.3	111.4
Missouri	7	595	652	611	608	97.9	107.2	100.5
Montana	A-7	462	474	421	474	97.5	100.0	88.8
Nebraska	A-3	208	207	220	213	97.7	97.2	103.3
Nevada	114	263	226	224	228	115.4	99.1	98.2
New Hampshire	3	538	565	437	513	104.9	110.1	85.2
Oklahoma	8	1,091	1,087	1,110	1,111	98.2	97.8	99.9
Pennsylvania	7	302	364	344	[4] 358	84.4	101.7	96.1
Rhode Island	3	325	337	307	326	99.7	103.4	94.2
South Carolina	104	676	687	694	665	101.7	103.3	104.4
Texas	8	863	821	877	848	101.8	96.8	103.4
	9	538	532	504	526	102.3	101.1	95.8
Utah	305	724	783	765	766	94.5	102.2	99.9
Washington	9	230	226	241	222	103.6	101.8	108.6
West Virginia	8	540	556	502	[5] 551	98.0	100.9	91.1
Alabama	6	614	671	701	667	92.1	100.6	105.0
California	4	772	808	736	829	93.1	97.5	88.8
Connecticut	4	716	752	630	[6] 757	94.6	99.3	83.2
Florida	11	393	375	350	381	103.1	98.4	91.9
Kansas	7	898	883	952	909	98.8	97.1	104.7
Kentucky	4	301	310	289	[7] 295	102.0	105.0	98.0
Maine	4	400	414	367	407	98.3	101.7	90.2
Maryland	3	386	421	401	376	102.7	112.0	106.6
Michigan	672	972	1,007	872	969	100.3	103.9	90.0
Pennsylvania	5	498	531	577	543	91.7	97.8	106.3
South Dakota	106	452	468	469	479	94.4	97.7	97.9
Wisconsin	16	892	934	993	998	89.4	93.6	99.5
Weighted average						97.5	100.5	97.8
Weighted percentage of error						4.05	3.12	5.65

[1] Oct. 29, 1938–Oct. 28, 1939.
[2] Aug. 6, 1938–Aug. 5, 1939.
[3] Aug. 20, 1938–Aug. 19, 1939.
[4] Oct. 1, 1938–Sept. 30, 1939.
[5] Mar. 18, 1939–Mar. 17, 1940.
[6] Feb. 18, 1939–Feb. 17, 1940.
[7] Year 1938.

A comparison on the basis of these weighted averages indicates that schedule I generally produces the most accurate results on State routes carrying heavy traffic, and that schedule II gives the most accurate values on State routes that carry light traffic. Considering all stations, the weighted average deviation of the ratios of computed traffic to true traffic is approximately equal for schedule I and II, and schedule III is generally less accurate than either of the others. However, it may be remarked that the average differences are small under all three schedules.

A better comparison of the results may be made by arranging the number of stations under each schedule according to the percentage deviation of the computed traffic from the true traffic volumes, as indicated in table 9.

Traffic at 73 of the 99 stations may be estimated under schedule I within 5 percent of the true values, as compared with 74 stations and 54 stations for schedules II and III, respectively. While 14 stations give results within 1 percent of true values under schedule III, as compared with 14 under schedule I, and 18 under schedule II, results at 45 stations are more than 5 percent inaccurate under schedule III as compared with but 26 stations under schedule I and 25 under schedule II.

From these tests, at a limited number of stations well distributed both geographically and with respect to traffic volumes, it would appear that schedule III produces results with a considerably wider range of deviation from true values than schedules I or II; that is, the results from the use of schedule III are much more erratic than those from either of the other schedules.

Accuracy is one of the most important considerations involved in selecting a schedule of operation. Cost of operation, completeness of resulting data, and practical time and distance factors involved in putting the schedule into field operation are frequently of equal importance.

In the State-wide Highway Planning Surveys, volume is but one of the many traffic items investigated. At loadometer and pit-scale stations, weight of vehicle, weight of loads, length, height, and width of vehicles, origin and destination of vehicle trips are a few of the many additional items with respect to which information is needed. Classification of vehicles by types is also necessary.

At loadometer and pit-scale stations, flags, flares, and protection signs must be placed, since vehicles must be stopped for weighing and questionnaires must be filled out. This preparation of a station for safe operation takes a considerable amount of time. This time requirement, together with the time needed to transport from one station to another personnel trained to obtain this type of information, makes practically impossible the use of a schedule based upon short periods of observation.

Use of a short period of observation reduces the amount of effective time (i. e., percentage of total time that stations are actually in operation) and greatly in-

TABLE 8.—*Automatic traffic recorder averages for year 1939, local routes*

State	Station	Average daily traffic: Schedule I	Schedule II	Schedule III	Actual average for year	Percentage of actual Average: I	II	III
Arkansas	10	250	266	268	[1] 259	96.5	102.7	103.5
Georgia	2	113	131	107	113	100.0	115.9	94.7
Iowa	609	96	93	107	96	100.0	96.9	111.5
	611	58	66	78	64	90.6	103.1	121.9
Kentucky	4	308	287	289	300	102.7	95.7	96.3
Maryland	8	341	344	363	349	97.7	98.6	104.0
Minnesota	169	130	134	122	[2] 136	95.6	98.5	89.7
	178	116	116	122	[3] 120	96.7	96.7	101.7
Montana	A-2	134	145	140	139	96.4	104.3	100.7
North Carolina	5	141	140	149	[3] 142	99.3	98.6	104.9
Ohio	5	155	176	160	172	90.1	102.3	93.0
South Dakota	105A	242	241	250	232	104.3	103.9	107.8
Texas	22	89	92	105	[4] 94	94.7	97.9	111.7
Wisconsin	19	186	185	196	195	95.4	94.9	100.5
Alabama	1	374	454	402	[5] 380	98.4	119.5	105.8
Massachusetts	3	209	225	175	[6] 213	98.1	105.6	82.2
	9	356	399	315	356	100.0	112.0	88.5
Michigan	683	335	325	311	330	101.5	98.5	94.2
Minnesota	177	547	533	526	567	97.5	94.0	92.8
	183	192	188	207	[7] 184	104.4	102.1	112.5
	184	229	202	203	[8] 199	115.1	101.5	102.0
Missouri	3	391	405	406	379	103.2	106.9	107.1
	4	440	491	431	470	93.6	104.4	91.7
North Carolina	6	213	231	182	[9] 213	100.0	108.5	85.4
	8	154	164	140	[10] 165	93.3	99.4	84.8
Ohio	3	241	257	242	[11] 261	92.3	98.5	92.7
	10	468	458	452	457	102.4	100.2	98.9
Oklahoma	10	562	558	549	558	100.7	100.0	98.4
Rhode Island	1	381	398	375	389	97.9	102.3	96.4
Texas	20	356	369	380	374	95.2	98.7	101.6
Utah	304	561	591	627	593	94.6	99.7	105.7
	307	1,500	1,660	1,585	1,593	94.2	104.2	99.5
Wisconsin	20	258	303	291	274	94.2	110.6	106.2
Weighted average						97.7	102.5	98.9
Weighted percentage of error						4.01	4.29	5.33

[1] Estimated.
[2] Aug. 6, 1938–Aug. 5, 1939.
[3] Aug. 20, 1938–Aug. 19, 1939.
[4] Nov. 19, 1938–Nov. 18, 1939.
[5] Apr. 30, 1939–Apr. 29, 1940.
[6] Jan. 15, 1939–Jan. 14, 1940.
[7] Jan. 29, 1938–Jan. 28, 1939.
[8] Mar. 26, 1938–Mar. 19, 1939.
[9] Sept. 11, 1938–Sept. 10, 1939.
[10] Feb. 13, 1938–Feb. 12, 1939.
[11] Year 1938.

TABLE 9.—*Number of stations at which computed traffic differs from actual traffic, under 3 assumed schedules; deviations by percentage groups*

Deviation of computed daily traffic from true daily traffic, percent	Number of stations: Schedule I	Schedule II	Schedule III
0–0.9	14	18	14
1–4.9	59	56	40
5–15	23	21	41
Over 15	3	4	4
Total	99	99	99

creases travel costs. Both these factors operate to increase very greatly the unit cost of an item of information, and thus the cost of the whole survey.

One advantage of either schedule I or II, as compared with schedule III, is that both provide much greater information with respect to normal maximum traffic volume. The maximum values recorded under either of the first two schedules are during periods of from 8 to 24 hours. Maximum values are ordinarily too irregular in their occurrence to permit an accurate measurement of them by means of a single hour of observation.

Still another consideration in the decision with respect to the most valuable schedule for field operation is the probable accuracy of the estimate of the proportions of the various types of vehicles—foreign vehicles, heavy trucks, busses, etc. in the results obtained with various schedules. This question is difficult to investigate, partly because of the scarcity of data. To be sure, the automatic traffic recorder has now given a considerable sample in which is known the total number of vehicles during every hour of the year. However, it is clear that the number of foreign vehicles, for example, in proportion to total vehicles changes greatly throughout the year.

In summer foreign vehicles form 50 percent of the total traffic in some States. In the same areas in winter foreign vehicles are not over 15 percent of the total. In one State foreign vehicles are 14 percent of the total in December and 24 percent in August. The distinction between vehicle types cannot be made by the automatic traffic recorder, and detailed data classifying traffic throughout every day of a full year are available for but a small number of locations.

A limited amount of investigation of this problem at one station, considered to be typical of traffic found on most rural highways, is summarized in table 10.

TABLE 10.—*Classification of traffic by type of vehicle under various schedules*

Item	Passenger cars: Local	Passenger cars: Foreign	Trucks and combinations	Busses	Total
Actual classification	78.2	7.1	14.5	0.2	100.0
Average of 8 runs (6 a. m.–10 p. m.) [1]	69.2	12.2	18.3	.3	100.0
Average of 8 runs (24 hour) [1]	69.2	11.9	18.7	.2	100.0
24-hour weekday, Saturday, and Sunday [2]	69.8	12.2	17.8	.2	100.0
24-hour weekday, Saturday, and Sunday [3]	84.6	3.2	11.9	.3	100.0
24-hour weekday, Saturday, and Sunday [4]	76.6	8.0	15.2	.2	100.0
16-hour (6 a. m.–10 p. m.) weekday, Saturday, and Sunday [4]	76.2	8.4	15.2	.2	100.0
8-hour (8 a. m.–4 p. m.) weekday, Saturday, and Sunday [4]	73.2	9.7	16.7	.4	100.0
Key station schedule (average of 5 runs)	78.0	6.8	15.0	.2	100.0
Average of 2 runs [5]	77.7	8.3	13.7	.3	100.0

[1] In months of probable maximum and probable minimum traffic.
[2] February and August.
[3] May and November.
[4] February, May, August, and November.
[5] 4-hour weekday, Saturday, and Sunday counts each season; staggered 8 a. m.–12 m. and 4 p. m.–8 p. m.

Other combinations, similar to those given in table 10, were examined and data for other stations were analyzed in the same manner. The tentative conclusion resulting from this analysis was that the standard key station schedule appears to give good results, but it is relatively a costly operation.

METHOD OF ESTIMATING TRAFFIC WITHIN CITIES OUTLINED

The above discussion includes an examination of the principal types of schedules that are, or have been, used in extensive traffic surveys on rural roads. Other schedules have been used in this work, but nearly all of them represent but minor modifications in the above general types.

Within cities, use has been made of a method of extremely short counts which was given practical application in a survey conducted in the city of Amarillo, Tex., by members of the Engineering and Police Departments in cooperation with the Texas Highway Department. [6]

Theoretically, under proper traffic conditions, a count of 1 minute during each half hour or hour might be sufficient for the estimate of total traffic, but the chief

[6] Traffic Aids to Texas Municipalities, by R. O. Swain. The American City, July 1940.

obstacle to this proposal was the loss of time involved by traveling between intersections. Finally, a 5-minute observation period was selected.

Time loss between stations was eliminated by stationing observers on the tops of the taller buildings in Amarillo. From certain of these buildings as many as 32 intersections could be observed. This procedure permitted a recorder to observe as many as six intersections within a half-hour period, counting traffic at each intersection for a 5-minute period.

The method used was described as follows:

In estimating the hourly flow of traffic, the two 5-minute counts taken within a 1-hour period were added together and multiplied by 6. This method of short counts in towns and cities was determined to be as accurate as making full 8-hour counts and converting them into 24-hour figures. In checking the accuracy against the full count, the error averaged approximately 3 percent. * * * Intersections carrying more than 4,000 vehicles in a 12-hour period were within 3 percent of accuracy.[6]

Study of reports and tests now available indicates that: (1) The key station schedule, or a schedule of the same general type, produces a larger proportion of results within practical limits of accuracy than do the other schedules; (2) the 40-hour schedule (No. III) previously described produces results with a considerably wider range of deviation from true values at more stations than either the blanket count control or the key station schedule; (3) the blanket count schedule produces results comparable with those from the key station schedule; (4) collection of information such as that obtained at loadometer and pit-scale stations is a difficult matter from the standpoint of travel time and practical scheduling of field parties, and is uneconomical when based upon a short count schedule; (5) the short count schedule produces insufficient information with respect to maximum traffic periods; (6) the key station schedule produces accurate results in the classification of traffic by vehicle types; (7) the short count schedule by 5-minute periods produces results within the limits of practical accuracy and is useful in city traffic surveys, if the time loss and cost of travel can be reduced by stationing observers on tall buildings from which several intersections can be observed.

COMPOSITION OF TRAFFIC ANALYZED

Further analysis with respect to certain of these conclusions will be greatly facilitated by the accumulation of automatic traffic recorder data. Certain data are now available from vehicle classification counts taken throughout 1939 at 352 automatic traffic recorder stations located in 39 States. These data are of assistance in forming conclusions with respect to schedule selection.

The total traffic was separated by type of vehicle by means of classification counts taken at intervals throughout the year at the recorder sites. The number of vehicle classification counts in some States is small and, in some instances, it was necessary to supplement them by classification data obtained in years other than 1939. However, the proportions of the various types of vehicles change slowly from year to year, and the inaccuracy in the number of vehicles by type is slight.

Two hundred and ninety-four of these stations were located on the State highway systems, and 58 were located on local roads. An examination of the data discloses significant differences between the characteristics of traffic on these two classes of highway. A comparison of the results of the automatic traffic recorder operation with gasoline consumption indicates that the recorders furnish a measure of traffic representative of the country as a whole and, in States which are operating a large number of recorders, representative of traffic changes.

In two States the classification of vehicles was not as detailed as that reported by the other States, so that the discussion which follows applies only to the results of operation at 334 stations (276 on State routes, 58 on local roads) in 37 States.

The proportion of foreign traffic using State highways varies widely among the States, and is affected by two major influences: (1) The geographical location and size of the State; (2) the amount of recreational traffic that is attracted to the State as compared with the amount of local traffic. It is probable that in few States are the automatic traffic recorders sufficient in number so that, if manual operations were made at each location, representative averages of the amount of foreign travel would be obtained. In Florida, which attracts large numbers of tourists, foreign cars measured at 10 traffic recorders were nearly 40 percent of the total traffic. Nevada attracts a small amount of tourist travel, but, because of its geographic location adjacent to the Pacific Coast States, foreign travel at 11 recorders in Nevada was found to be nearly 40 percent of the total. Near the other extreme is Texas, in which foreign travel was slightly more than 10 percent, measured at 18 traffic recorders. Texas attracts a small amount of tourist traffic relative to its total traffic and is not crossed much by foreign vehicles en route to other States.

For all States, the percentage of foreign vehicles measured at automatic traffic recorders was 21.08 on State highways, and 1.72 on local routes, a ratio of more than 12 to 1.

Bus traffic was found to be less than 1 percent (0.88 percent) of traffic on State highways and negligible in amount upon local routes although, because of the low volume of travel on local routes, it amounted to 1.72 percent of the total. Busses are predominantly local vehicles; 14 out of 15 busses traveling State highways carry tags of the State in which they operate, and bus travel on local routes is almost entirely by local vehicles.

Heavy trucks (those with rated capacities of 5 tons, or more) use the highways but slightly more than do busses. They were found to be 1.01 percent of all vehicles measured at automatic traffic recorder stations, and nearly all were found on State highways. Eleven percent of heavy trucks counted were foreign vehicles as against 7 percent of the busses.

While the foregoing statement about the number of heavy trucks is true with regard to totals, an inspection of the detailed data discloses concentrations of heavy trucks much greater than those of busses. At several of the recorders located in California, Connecticut, Massachusetts, and Pennsylvania, heavy trucks averaged upwards of 100 per day during 1939 and reached 667 per day at stations 8 and 19 in Connecticut. At the single station for which data were available in Illinois, heavy trucks averaged 270 per day, while bus traffic at this station was but 13 per day.

A study of data for individual stations indicates a slight tendency toward increase in the proportion of heavy trucks with increase in volume of total traffic;

[6] Traffic Aids to Texas Municipalities, by R. O. Swain. The American City, July 1940.

i. e., the percentage of heavy trucks tends to increase with an increase in the total number of vehicles using a route. In contrast, the percentage of foreign vehicles decreases generally with an increase in the total number of vehicles, although this tendency is not sharply marked.

From traffic counter records it is now possible to measure the seasonal variation in traffic volume during 1939 upon State and local routes, as indicated in table 11. Seasonal variation is similar on the two classes of routes, although the travel peak is earlier and higher on the State routes. The seasonal peak on State highways is in August, travel in that month exceeding that of the average month by nearly 24 percent. Travel on local routes is greatest in September and is about 17 percent greater than in the average month.

TABLE 11.—*Seasonal variation in total motor-vehicle traffic on State highways and local roads*

Month	Average daily traffic		Percentage of average month	
	State highways	Local routes	State highways	Local routes
January	1,608	276	75.68	80.00
February	1,607	245	75.63	71.01
March	1,838	278	86.50	80.58
April	2,018	311	94.98	90.14
May	2,165	335	101.89	97.10
June	2,306	358	108.53	103.77
July	2,594	394	122.09	114.20
August	2,633	396	123.93	114.79
September	2,384	403	112.20	116.82
October	2,233	390	105.09	113.04
November	2,104	384	99.02	111.30
December	2,007	370	94.46	107.25

SEASONAL VARIATIONS IN TRAFFIC FLOW COMPARED

The automatic traffic recorder data have been of invaluable assistance in the solution of another problem—that of estimating annual traffic volume when the period that traffic was observed covered but a few hours. There are hundreds of thousands of miles of public highways upon which traffic volume is below 25 vehicles per day, and only a limited expenditure for traffic information is justified upon such routes. At many intermediate points between key stations upon routes of considerable traffic importance, traffic need be observed only during short periods of time to produce acceptable data with regard to variation of traffic. At such points a factor derived from known traffic patterns (frequently from the continuous data collected at automatic recorders) can be applied in estimating annual traffic.

These factors must be based upon traffic patterns that are typical and reasonably invariant over a period of time; that is, they must be typical, or representative, in order that they will apply to many stations. They must be reasonably invariant because, if sharp changes occur in seasonal patterns (or other patterns needed), the factors derived for use in one year will not produce accurate estimates of annual traffic when applied to traffic data for short periods of time in later years. The term "reasonably invariant" is used because experience indicates that absolute invariance in patterns is not to be expected.

One measure of the invariance in seasonal traffic variation is presented in table 12, which shows seasonal variation of urban and rural traffic for each year from 1926 to 1931, inclusive, in Virginia. These figures are taken from graphs which accompany annual traffic flow maps prepared by the Virginia Highway Commission. Traffic data are available for the whole State highway system and are shown in the maps. The table indicates the remarkable lack of substantial change in the seasonal indices for both urban and rural traffic during these 6 years.

Other comparisons are shown in figures 19 to 23, inclusive, for Arkansas, Connecticut, Florida, Ohio, and Pennsylvania, respectively. In each of these States comparison has been made between the seasonal characteristics derived from former traffic surveys, with the seasonal characteristics of traffic at the automatic traffic recorder stations in each State operated during the year 1939. In each case the data are related to the average monthly traffic volume as 100 percent.

The number of traffic recorders operated in 1939 is much smaller than the number of stations from which the original seasonal indices were obtained. In the comparisons, data from States with the largest number of traffic recorders and an early traffic survey were used. Two of the States, Connecticut and Pennsylvania, each operated 22 traffic recorders during 1939; and in no State was the number of recorders less than 10.

TABLE 12.—*Seasonal variations in traffic on Virginia State highways* [1]

[Monthly variation in percentage of average monthly traffic]

Month	1926		1927		1928		1929		1930		1931	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
January	73	73	73	73	73	73	73	73	72	72	72	72
February	71	73	70	73	71	73	71	72	71	72	71	73
March	73	98	73	98	74	98	73	98	73	98	74	98
April	95	102	95	102	95	101	95	102	95	102	95	102
May	104	101	104	101	103	100	103	101	104	102	104	101
June	106	98	106	98	106	98	105	98	105	98	105	98
July	112	99	112	99	112	99	112	99	112	99	112	99
August	123	135	124	135	123	134	124	134	124	134	123	134
September	115	118	115	118	114	118	115	118	115	118	114	118
October	112	102	112	102	112	102	112	102	112	102	113	102
November	111	100	111	100	111	102	111	102	111	102	111	102
December	105	101	105	101	106	102	106	101	106	101	106	101

[1] Sections of highways within a 10-mile radius of cities are designated as urban, others as rural, by Virginia Highway Commission.

The Arkansas comparison, figure 19, shows a very slight change in seasonal variation from 1934–35 to 1939. In Connecticut, figure 20, the changes in seasonal variation are small. In Florida, the indices are also fairly close.

In Ohio the comparison of seasonal variation is between the years 1925 and 1939. Here the agreement is not so close as in the previous examples. And finally, in Pennsylvania, the comparison is for 1923–24 with 1939 and there is still greater disagreement between the indices than in Ohio. The data shown by these figures indicate that traffic volume has tended to be more evenly distributed throughout the year in the latter part of the last 15- to 17-year period.

In figure 23 the change from minimum to maximum values of the seasonal index in 1923–24 was from about 40 to 160, a ratio of 1 to 4. Corresponding values in 1939 are from a minimum of 65 to a maximum of 133, a ratio of 1 to 2.

Thus, while there has been a considerable change in seasonal indices over the longer period, with the increased reliability of operation of motor vehicles, better roads, and snow removal over the whole highway system, during the latter part of the period under discussion the apparent change in seasonal variation has been small.

TRAFFIC FLOW BETWEEN 7 A. M. AND 7 P. M. APPROXIMATELY 70 PERCENT OF DAILY TOTAL

It may also be noted that this relative invariance in seasonal change during the latter part of the period is more or less independent of the particular type of seasonal variation under consideration. For example, Florida's seasonal traffic indices differ widely from those of Arkansas and even more widely from those of Connecticut. The minimum traffic in Florida is in September; whereas in Arkansas, it is in January; and in Connecticut, it is in February. Nevertheless the change in seasonal variation is nearly the same for all three States.

There are other patterns of traffic that are reasonably invariant in the sense in which that term has previously been used. Tables 13, 14, and 15 contain data from automatic recorders on State routes, divided between heavy and light traffic routes, and on local routes, together with the computed ratios of several period totals to total daily traffic. An examination of these tables discloses interesting and significant facts. For example, the percentage of the total traffic moving between 7 a. m. and 7 p. m. is 71.9 for all routes and by classified routes is:

	Percent
15 State routes, heavy traffic	71. 0
21 State routes, light traffic	75. 8
14 Local routes	78. 1

R. O. Swain, in the article from The American City previously referred to, states:

That hourly traffic flow also cuts certain patterns is another Cherniack theory which may be applied to Texas traffic. Of value in this connection is the movement of motor-vehicle traffic

TABLE 13.—*Traffic by hourly periods at automatic recorder stations, State routes, heavy traffic, 1939*

State	Station No.	Total yearly volume	Volume by time of day					Percentage of total volume				
			6 a. m. to 2 p. m.	2 p. m. to 10 p. m.	10 p. m. to 6 a. m.	8 a. m. to 4 p. m.	7 a. m. to 7 p. m.	6 a. m. to 2 p. m.	2 p. m. to 10 p. m.	10 p. m. to 6 a. m.	8 a. m. to 4 p. m.	7 a. m. to 7 p. m.
Massachusetts	1	1, 045, 290	357, 007	558, 993	129, 290	438, 746	720, 648	34. 2	53. 5	12. 3	42. 0	68. 9
	8	2, 110, 370	801, 639	1, 040, 069	268, 662	966, 815	1, 490. 998	38. 0	49. 3	12. 7	45. 8	70. 7
Connecticut	2	[1] 1, 365, 076	475, 784	624, 939	264, 353	590, 833	901, 065	34. 8	45. 8	19. 4	43. 3	66. 0
	17	[2] 2, 949, 154	1, 014, 094	1, 396, 555	538, 505	1, 194, 075	1, 913, 666	34. 4	47. 3	18. 3	40. 5	64. 9
Florida	10	1, 260, 823	548, 867	576, 310	135, 646	657, 113	961, 999	43. 5	45. 7	10. 8	52. 1	76. 3
	13	658, 659	274, 331	316, 150	68, 178	313, 335	493, 356	41. 6	48. 0	10. 4	47. 6	74. 9
Michigan	676	1, 265, 045	490, 464	623, 114	151, 467	596, 616	912, 106	38. 8	49. 2	12. 0	47. 2	72. 1
Louisiana	14	1, 109, 565	463, 276	516, 364	129, 925	543, 593	830, 583	41. 8	46. 5	11. 7	49. 0	74. 9
Missouri	9	1, 879, 116	704, 713	930, 552	243, 851	827, 618	1, 305, 289	37. 5	49. 5	13. 0	44. 0	69. 5
Texas	10	510, 302	228, 814	237, 471	44, 017	262, 527	401, 863	44. 9	46. 5	8. 6	51. 4	78. 7
Colorado	11	[3] 1, 944, 663	809, 980	924, 853	209, 830	945, 578	1, 452, 261	41. 6	47. 6	10. 8	48. 6	74. 7
Washington	10	1, 200, 884	495, 714	585, 353	119, 817	578, 385	892, 854	41. 3	48. 7	10. 0	48. 2	74. 3
Oregon	2	337, 721	148, 001	150, 424	39, 296	183, 120	256, 884	43. 8	44. 6	11. 6	54. 2	76. 1
California	5	289, 015	119, 347	142, 217	27, 451	153, 775	225, 398	41. 3	49. 2	9. 5	53. 2	78. 0
	10	1, 399, 962	538, 271	619, 621	242, 070	657, 227	960, 344	38. 4	44. 3	17. 3	46. 9	68. 6
Total		19, 325, 645	7, 470, 302	9, 242, 985	2, 612, 358	8, 909, 356	13, 719, 314	38. 7	47. 8	13. 5	46. 1	71. 0

[1] Feb. 18, 1938–Feb. 17, 1939. [2] Feb. 25, 1939–Feb. 24, 1940. [3] Dec. 17, 1938–Dec. 16, 1939.

TABLE 14.—*Traffic by hourly periods at automatic recorder stations, State routes, light traffic, 1939*

State	Station No.	Total yearly volume	Volume by time of day					Percentage of total volume				
			6 a. m. to 2 p. m.	2 p. m. to 10 p. m.	10 p. m. to 6 a. m.	8 a. m. to 4 p. m.	7 a. m. to 7 p. m.	6 a. m. to 2 p. m.	2 p. m. to 10 p. m.	10 p. m. to 6 a. m.	8 a. m. to 4 p. m.	7 a. m. to 7 p. m.
Arizona	5	72, 311	31, 060	35, 688	5, 563	38, 860	58, 239	43. 0	49. 3	7. 7	53. 7	80. 5
Arkansas	7	63, 629	30, 821	28, 739	4, 069	34, 725	51, 509	48. 4	45. 2	6. 4	54. 6	81. 0
Georgia	11	100, 559	42, 729	50, 124	7, 706	52, 483	77, 861	42. 5	49. 8	7. 7	52. 2	77. 4
Iowa	607	154, 537	65, 870	74, 135	14, 532	81, 364	118, 994	42. 6	48. 0	9. 4	52. 7	77. 0
Louisiana	13	[1] 54, 938	29, 262	22, 097	3, 579	31, 850	46, 445	53. 3	40. 2	6. 5	58. 0	84. 5
Minnesota	171	[2] 91, 365	36, 512	44, 943	9, 910	46, 443	66, 759	40. 0	49. 2	10. 8	50. 8	73. 1
	174	[3] 107, 561	52, 349	49, 145	6, 067	60, 716	85, 521	48. 7	45. 7	5. 6	56. 4	79. 5
Missouri	7	212, 287	91, 694	103, 239	17, 354	109, 796	165, 286	43. 2	48. 6	8. 2	51. 7	77. 9
Montana	A-7	173, 345	65, 897	89, 974	17, 474	85, 732	128, 910	38. 0	51. 9	10. 1	49. 5	74. 4
Nebraska	A-3	77, 735	32, 381	38, 198	7, 156	39, 365	59, 004	41. 7	49. 1	9. 2	50. 6	75. 9
Nevada	114	83, 728	35, 063	41, 519	7, 146	43, 385	65, 096	41. 9	49. 6	8. 5	51. 8	77. 7
New Hampshire	3	178, 359	78, 442	88, 170	11, 747	98, 509	141, 225	44. 0	49. 4	6. 6	55. 2	79. 2
Oklahoma	8	292, 276	118, 045	143, 160	31, 071	143, 739	217, 263	40. 4	49. 0	10. 6	49. 2	74. 3
Pennsylvania	7	[4] 130, 672	50, 721	68, 134	11, 817	58, 975	93, 890	38. 8	52. 1	9. 1	45. 1	71. 9
Rhode Island	3	118, 034	42, 640	63, 706	11, 688	54, 334	84, 617	36. 1	54. 0	9. 9	46. 0	71. 7
South Carolina	104	244, 745	101, 309	114, 861	28, 575	120, 267	179, 797	41. 4	46. 9	11. 7	49. 1	73. 5
Texas	8	287, 269	113, 812	140, 050	33, 407	136, 034	206, 308	39. 6	48. 8	11. 6	47. 4	71. 8
	9	180, 932	68, 411	95, 733	16, 788	81, 180	132, 950	37. 8	52. 9	9. 3	44. 9	73. 5
Utah	305	258, 738	111, 994	122, 549	24, 195	133, 345	199, 005	43. 3	47. 4	9. 3	51. 5	76. 9
Washington	9	71, 984	30, 552	35, 312	6, 120	38, 070	56, 209	42. 4	49. 1	8. 5	52. 9	78. 1
West Virginia	8	[5] 157, 409	69, 344	76, 527	11, 538	85, 479	125, 615	44. 1	48. 6	7. 3	54. 3	79. 8
Total		3, 112, 413	1, 298, 908	1, 526, 003	287, 502	1, 574, 651	2, 360, 503	41. 7	49. 0	9. 3	50. 6	75. 8

[1] Oct. 29, 1938–Oct. 28, 1939. [2] Aug. 6, 1938–Aug. 5, 1939. [3] Aug. 20, 1938–Aug. 19, 1939. [4] Oct. 1, 1938–Sept. 30, 1939. [5] Mar. 18, 1939–Mar. 17, 1940.

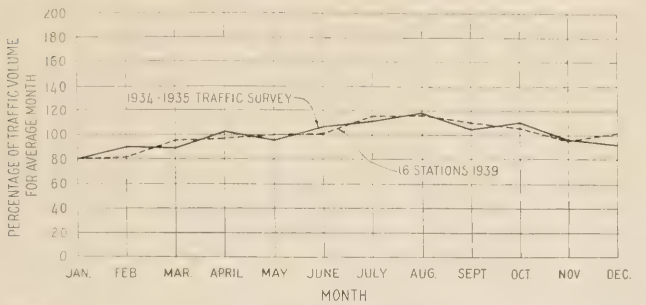

FIGURE 19.—CHANGES IN SEASONAL VARIATION OF TRAFFIC FLOW IN ARKANSAS.

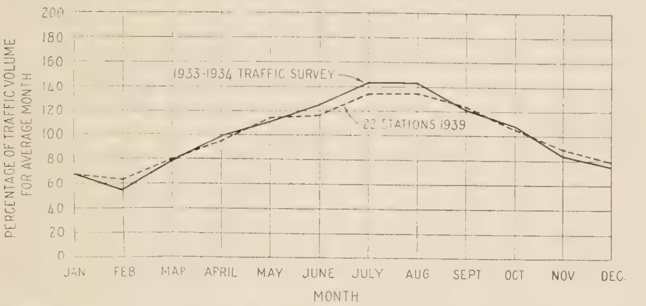

FIGURE 20.—CHANGES IN SEASONAL VARIATION OF TRAFFIC FLOW IN CONNECTICUT.

between 7 a. m. and 7 p. m. Between these "daylight" hours, Cherniack figures show that approximately 70 percent of the traffic moves in both rural and urban areas. On Texas highways, according to data taken from the highway planning survey's 20 automatic traffic recorders, this "daylight" percentage is 73.23.

Thus the data shown in these tables agree with results obtained elsewhere. It is also significant that the proportion of traffic moving during daylight is greater on the local routes (78.1 percent) as compared with the proportion on heavily traveled State routes (71.0 percent).

Traffic during the period from 10 p. m. to 6 a. m. on the various classes of routes is 12.7 percent of the full 24-hour traffic, and is classified by routes as follows:

	Percent
State routes, heavy traffic	13.5
State routes, light traffic	9.3
Local routes	7.3

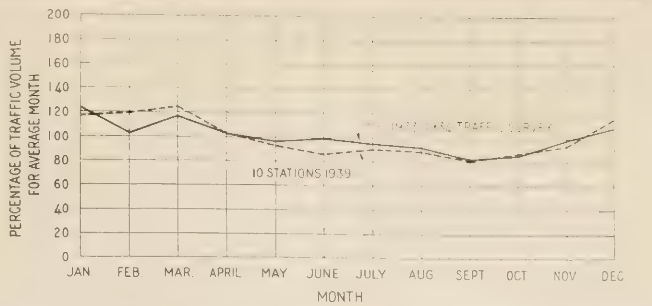

FIGURE 21.—CHANGES IN SEASONAL VARIATION OF TRAFFIC FLOW IN FLORIDA.

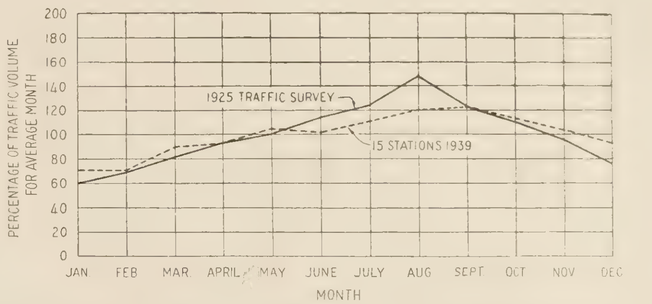

FIGURE 22.—CHANGES IN SEASONAL VARIATION OF TRAFFIC FLOW IN OHIO.

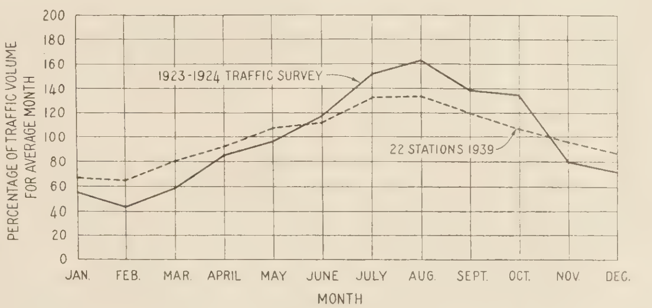

FIGURE 23.—CHANGES IN SEASONAL VARIATION OF TRAFFIC FLOW IN PENNSYLVANIA.

TABLE 15.—*Traffic by hourly periods at automatic-recorder stations, local routes, 1939*

State	Station No.	Total yearly volume	Volume by time of day					Percentage of total volume				
			6 a. m. to 2 p. m.	2 p. m. to 10 p. m.	10 p. m. to 6 a. m.	8 a. m. to 4 p. m.	7 a. m. to 7 p. m.	6 a. m. to 2 p. m.	2 p. m. to 10 p. m.	10 p. m. to 6 a. m.	8 a. m. to 4 p. m.	7 a. m. to 7 p. m.
Arkansas	10	74,190	36,487	33,926	3,777	40,599	60,699	49.2	45.7	5.1	54.7	81.8
Georgia	2	41,156	18,965	19,958	2,233	21,575	33,702	46.1	48.5	5.4	52.4	81.9
Iowa	609	34,114	15,051	16,377	2,686	18,039	26,314	44.1	48.0	7.9	52.9	77.1
	611	23,356	11,810	10,218	1,328	14,221	19,586	50.6	43.7	5.7	60.9	83.9
Kentucky	4	105,911	48,342	49,544	8,025	52,402	82,129	45.6	46.8	7.6	49.5	77.5
Maryland	8	127,563	58,386	58,588	10,589	63,817	95,230	45.8	45.9	8.3	50.0	74.7
Minnesota	169	[1] 49,477	25,646	19,960	3,871	27,970	38,409	51.8	40.4	7.8	56.5	77.6
	178	[2] 43,396	21,171	19,910	2,315	24,388	34,898	48.8	45.9	5.3	56.2	80.4
Montana	A-2	49,019	19,449	25,801	3,769	24,976	37,969	39.7	52.6	7.7	51.0	77.5
North Carolina	5	[2] 51,653	22,429	26,259	2,965	27,054	41,559	43.5	50.8	5.7	52.4	80.5
Ohio	5	47,332	22,701	22,226	2,405	27,681	38,701	48.0	47.0	5.0	58.5	81.8
South Dakota	105A	86,127	35,792	42,478	7,857	43,298	65,770	41.6	49.3	9.1	50.3	76.4
Texas	22	[3] 29,887	13,218	14,692	1,977	15,530	23,754	44.2	49.2	6.6	52.0	79.5
Wisconsin	19	66,841	27,836	32,600	6,405	32,843	49,750	41.6	48.8	9.6	49.1	74.4
Total		830,022	377,283	392,537	60,202	434,393	648,470	45.4	47.3	7.3	52.3	78.1
Grand total, tables 13, 14, and 15		23,268,080	9,146,493	11,161,525	2,960,062	10,918,400	16,728,287	39.3	48.0	12.7	46.9	71.9

[1] Aug. 6, 1938–Aug. 5, 1939. [2] Aug. 20, 1938–Aug. 19, 1939. [3] Nov. 19, 1938–Nov. 18, 1939.

Thus, the percentage of total traffic carried during the period from 10 p. m. to 6 a. m. for local routes is only half that for heavily traveled State routes.

The percentages of the total daily traffic shown in tables 13, 14, and 15 indicate that the 8 a. m. to 4 p. m. period is the best 8-hour period from the standpoint of uniformity of results for light-traffic routes, whether these routes be State highways or local routes. Records for 86 percent of the local routes vary less than 5 percent from the average during that 8-hour period, as compared with 81 percent for the light-traffic routes and 66 percent for the heavy-traffic routes on the State highway system.

These "reasonably invariant" ratios provide a measure of the accuracy of estimates of total yearly traffic volume made from traffic samples taken during relatively short periods of observation. The methods of deriving factors and their application have previously been discussed in PUBLIC ROADS.[3]

The results of automatic traffic recorder operations permit an analysis of the trends of traffic and, as the record accumulates, will be of increasing value for this purpose. As indicated in table 1, in 1937 there were 199 recorders in operation. However, not all of these were operated for the full year. While the record is now rather short, it may be stated that over this period the percentage increases in traffic at all stations closely approximate the increase in gasoline consumption.

[3] Highway Traffic Analysis Methods and Results, by L. E. Peabody. PUBLIC ROADS, vol. 10, No. 1, March 1929.

It seems likely that the traffic data might provide a measure of business activity, both in general and for small areas or regions. The fact that both trucks and passenger cars are in the stream of traffic means that the data reflect business traffic as well as pleasure or recreational traffic. And since from 80 to 85 percent of all trips outside city limits are less than 20 miles in length,[8] local characteristics must be well represented in the data. These characteristics are essential in an index of regional business activity and, properly weighted, should combine to provide equally good indices of national business activity.

The chief value of knowing the trends of traffic is their usefulness in estimating future traffic. When it is recalled that many of the elements of the highway have a long life and that some of them, structures such as bridges for example, frequently require large expenditures, the importance of an estimate of future traffic is apparent.

The traffic estimate also provides a basis for estimating future highway income and thus permits the setting up of a rational budget for highways. The more accurate and representative the traffic trend, the more dependable and useful will be future plans of improvement. The automatic recorders furnish a volume of data covering a wide-spread area that are more accurate and more useful in trend analysis than any previously gathered.

[8] Preliminary Results of Road-Use Studies, by R. H. Paddock and R. P. Rodgers, PUBLIC ROADS, vol. 20, No. 3, May 1939.

CURRENT STATUS OF UNITED STATES WORKS PROGRAM HIGHWAY PROJECTS

(AS PROVIDED BY THE EMERGENCY RELIEF APPROPRIATION ACT OF 1935)

AS OF DECEMBER 31, 1940

STATE	APPORTIONMENT	COMPLETED			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
		Estimated Total Cost	Works Program Funds	Miles	Estimated Total Cost	Works Program Funds	Miles	Estimated Total Cost	Works Program Funds	Miles	
Alabama	$ 4,151,115	$ 4,224,798	$ 4,131,250	144.1	$ 19,864	$ 19,864	0.1				
Arizona	2,569,841	3,172,141	2,531,293	193.8	38,548	38,548					
Arkansas	3,352,061	3,366,371	3,333,924	363.4	18,137	18,137	.3				
California	7,747,928	8,293,122	7,747,928	262.7							
Colorado	3,395,263	3,300,163	3,182,248	113.7	194,968	194,968	.5				$ 18,047
Connecticut	1,418,709	1,570,314	1,394,591	22.7							24,118
Delaware	900,310	878,199	842,562	69.9							57,748
Florida	2,597,144	2,641,713	2,550,786	99.1	46,358	46,358	2.8				
Georgia	4,988,967	4,961,757	4,586,851	265.3	270,655	270,655	7.3	$ 66,224	$ 66,224	4.1	65,238
Idaho	2,222,747	2,346,077	2,222,747	187.4							
Illinois	8,694,009	9,073,672	8,694,009	518.5							
Indiana	4,941,255	5,635,125	4,941,255	239.2							
Iowa	4,991,664	5,356,873	4,989,104	528.6	3,899	2,560	.1				
Kansas	4,994,975	4,961,177	4,946,626	393.1	48,349	48,349	.4				
Kentucky	3,726,271	3,962,495	3,722,642	359.0							3,629
Louisiana	2,890,429	3,271,682	2,860,959	177.6	31,580	29,470					
Maine	1,676,799	1,707,665	1,676,799	77.6							
Maryland	1,750,738	1,822,945	1,696,484	44.8	52,000	46,859	.5				7,395
Massachusetts	3,262,885	4,249,700	3,184,283	19.2	49,328	49,321					29,281
Michigan	6,301,414	7,123,481	6,301,414	293.0							
Minnesota	5,277,145	6,516,457	5,272,746	901.6	4,399	4,399					
Mississippi	3,457,552	3,448,631	3,438,032	236.7				19,519	19,519	.3	
Missouri	6,012,652	6,142,947	6,012,652	777.5							
Montana	3,676,416	3,713,370	3,676,416	207.4							
Nebraska	3,870,739	3,962,855	3,826,572	374.6	31,896	31,896	.5				12,272
Nevada	2,243,074	2,423,114	2,243,074	110.2							
New Hampshire	945,225	987,794	940,765	42.0				4,568	4,460	.2	
New Jersey	3,129,805	3,337,889	3,073,505	35.7	46,947	46,947					9,353
New Mexico	2,871,397	2,878,564	2,869,041	213.6							2,356
New York	11,046,377	11,054,928	10,643,474	178.6	318,258	318,258	1.3	51,000	42,912	.6	41,733
North Carolina	4,720,173	4,800,532	4,720,173	289.2							
North Dakota	2,867,245	2,921,382	2,867,245	424.1							
Ohio	7,670,815	7,697,039	7,555,753	306.3	115,062	115,062					
Oklahoma	4,580,670	4,862,779	4,580,670	411.8							
Oregon	3,038,642	3,218,985	3,036,134	164.4							2,508
Pennsylvania	9,347,797	10,308,396	9,061,828	279.4	447,874	212,017	5.3	63,255	63,255	3.2	10,697
Rhode Island	989,208	1,113,526	989,208	18.8							
South Carolina	2,702,012	3,046,557	2,693,440	250.5	14,100	8,572					
South Dakota	2,976,454	2,987,929	2,976,454	513.8							
Tennessee	4,192,460	4,313,835	4,192,460	153.0							
Texas	11,989,350	13,141,777	11,989,350	1,126.6							
Utah	2,067,154	2,398,268	2,067,154	207.5							
Vermont	924,306	1,077,392	924,306	23.2							
Virginia	3,652,667	4,108,154	3,617,651	838.7	20,268	20,268					14,748
Washington	3,026,161	3,456,513	3,026,161	165.3							
West Virginia	2,231,412	2,535,594	2,197,783	100.5							33,629
Wisconsin	4,823,884	5,317,867	4,823,884	343.8							
Wyoming	2,219,155	2,227,966	2,219,155	155.0							
District of Columbia	949,496	950,000	949,496	8.8							
Hawaii	926,033	1,023,143	926,033	18.2							
TOTALS	195,000,000	207,893,653	192,948,370	13,249.5	1,772,490	1,522,508	19.1	204,566	196,370	8.4	332,752

CURRENT STATUS OF UNITED STATES WORKS PROGRAM GRADE CROSSING PROJECTS

(AS PROVIDED BY THE EMERGENCY RELIEF APPROPRIATION ACT OF 1935)

AS OF DECEMBER 31, 1940

STATE	APPORTIONMENT	COMPLETED					UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
		Estimated Total Cost	Works Program Funds	NUMBER			Estimated Total Cost	Works Program Funds	NUMBER			Estimated Total Cost	Works Program Funds	NUMBER			
				Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise			Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise			Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	
Alabama	$ 4,034,617	$ 4,077,966	$ 4,013,492	54	2	12											$ 21,125
Arizona	1,256,099	1,303,815	1,217,704	15		7	$ 38,395	$ 38,395	2								
Arkansas	3,574,060	3,539,943	3,529,424	61	6	38	43,086	43,086									1,550
California	7,486,362	7,397,881	7,291,638	49	8	9	390,358	184,828	5								9,897
Colorado	2,631,567	2,643,408	2,569,252	30	3	27	61,208	61,208	1								1,107
Connecticut	1,712,684	1,593,553	1,573,492	9	2							$ 129,320	$ 128,444	1			10,748
Delaware	418,239	410,879	407,027	3													11,212
Florida	2,827,883	2,693,132	2,666,700	32	5	81	68,726	68,726	1								92,457
Georgia	4,895,949	3,852,003	3,582,662	64	16	60	120,144	120,144	1	2		111,356	111,356	2	2	4	1,081,787
Idaho	1,674,479	1,735,174	1,643,213	24	2	21						31,266	31,266	2			
Illinois	10,307,184	10,485,453	10,172,902	81	6		128,000	128,000		2							6,282
Indiana	5,111,096	5,383,293	4,997,797	42	15	163						116,200	113,298	1			
Iowa	5,600,679	5,787,906	5,588,962	108	9	8											11,717
Kansas	5,246,258	5,675,472	5,246,258	62	1	8											
Kentucky	3,672,387	3,754,416	3,537,407	27	13		190,024	134,281	1								700
Louisiana	3,213,467	3,086,514	3,049,366	30	3							158,498	158,498	3		14	5,603
Maine	1,426,861	1,435,159	1,416,643	20	4	4											10,218
Maryland	2,061,751	1,953,573	1,897,405	20	4	31	31,793	31,793		1							132,553
Massachusetts	4,210,833	4,012,883	3,987,617	28	4		145,395	138,962	1								84,254
Michigan	6,765,197	7,240,114	6,765,197	46	9												
Minnesota	5,395,441	5,483,227	5,394,329	86	15	50											1,112
Mississippi	3,241,475	3,216,129	3,205,792	62	7	28	4,780	4,780			2	7,460	7,460			3	23,443
Missouri	6,142,153	6,190,382	6,126,142	50	1												16,011
Montana	2,722,327	2,708,439	2,682,774	38	9		39,553	39,553	2								
Nebraska	3,556,441	3,428,924	3,369,502	85	3	23	186,939	186,939		1							
Nevada	887,260	912,949	887,260	9	3	3											
New Hampshire	822,484	840,475	803,800	10	4	7	18,684	18,684									
New Jersey	3,983,826	3,927,039	3,901,833	24	10	1	59,757	59,757									22,236
New Mexico	1,725,286	1,735,367	1,725,286	20	1	1											
New York	13,577,189	13,375,211	12,821,374	52	51		258,848	258,448		1							497,367
North Carolina	4,823,958	4,767,122	4,747,520	66	20	125						34,140	34,140			6	42,298
North Dakota	3,207,473	3,225,591	3,194,536	57	5												12,937
Ohio	8,439,897	8,617,125	7,915,169	51	8	14	126,598	126,598				388,062	357,000	1			41,130
Oklahoma	5,004,711	5,090,350	4,998,336	68	13	41											6,375
Oregon	2,334,204	2,392,554	2,324,175	17	7	2											10,029
Pennsylvania	11,483,613	11,372,784	10,666,619	86	22	9	486,261	486,261	3			115,846	115,846	1			214,887
Rhode Island	699,691	702,391	692,910	4	3		6,781	6,781									
South Carolina	3,059,956	3,002,428	2,893,217	49	19	47	22,381	22,381		1							144,358
South Dakota	3,249,086	3,278,998	3,249,086	76	5	76											
Tennessee	3,903,979	3,801,670	3,724,202	48	5	55	91,718	91,718		1		10,842	10,842			4	77,217
Texas	10,855,982	10,585,942	10,447,388	131	15	148	407,187	407,187	6								1,406
Utah	1,230,763	1,281,515	1,230,763	16	1	1											
Vermont	729,857	772,285	729,857	10	7	20											
Virginia	3,774,287	3,731,626	3,537,065	54	21	27	82,998	82,998	1			7,000	7,000			1	147,224
Washington	3,095,041	3,093,833	3,054,438	24	12	11	40,603	40,603									
West Virginia	2,677,937	2,669,262	2,595,213	28	4	7											82,724
Wisconsin	5,022,683	5,032,188	4,978,640	39	8	36	27,681	27,681			7	18,026	16,362			3	
Wyoming	1,360,841	1,364,049	1,356,655	15			4,186	4,186									
District of Columbia	410,804	432,570	410,804	3													
Hawaii	453,703	456,549	453,703	5													
TOTALS	196,000,000	195,551,511	189,272,546	2,088	391	1201	3,082,064	2,813,978	24	9	9	1,128,016	1,091,512	11	2	35	2,821,964

STATUS OF FEDERAL-AID HIGHWAY PROJECTS

AS OF DECEMBER 31, 1940

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 2,858,664	$ 1,421,234	95.1	$ 5,150,759	$ 2,562,510	189.9	$ 994,020	$ 494,210	32.3	$ 1,767,202
Arizona	1,032,363	680,891	47.7	1,372,484	947,014	62.4	875,873	456,341	22.4	547,729
Arkansas	4,281,884	2,003,437	117.1	1,225,138	611,234	55.4	328,272	164,095	8.5	259,294
California	5,245,741	2,680,057	107.9	8,243,310	4,360,359	120.3	2,002,255	1,034,540	43.5	700,445
Colorado	2,009,290	1,103,155	186.8	2,142,320	1,226,351	82.6	547,420	308,526	85.0	1,721,244
Connecticut	1,696,143	833,513	15.2	1,268,769	608,618	11.3	159,030	77,409	1.0	1,026,887
Delaware	531,373	265,280	16.1	1,661,300	803,618	16.5				1,040,813
Florida	2,365,696	1,178,660	62.5	1,952,893	968,075	59.4	1,205,275	572,008	21.0	2,016,396
Georgia	2,950,486	1,467,507	182.1	7,094,248	3,547,624	275.2	1,813,878	906,939	84.6	4,759,094
Idaho	1,377,527	838,707	147.4	1,151,993	708,730	60.5	259,956	160,341	7.5	1,213,439
Illinois	5,317,670	2,629,572	137.1	7,893,692	3,946,481	141.2	2,698,300	1,349,150	82.9	1,393,069
Indiana	4,299,598	2,114,095	101.0	6,720,664	3,254,186	102.8	2,052,430	1,007,545	33.7	454,145
Iowa	5,204,137	2,421,733	177.1	4,136,513	1,862,459	130.9	808,508	357,016	35.6	151,439
Kansas	3,498,770	1,725,962	285.5	5,926,103	2,981,814	361.1	2,812,668	1,394,316	169.1	2,676,133
Kentucky	2,580,865	1,285,947	81.9	2,899,237	1,449,618	77.0	1,236,926	618,463	44.8	2,475,704
Louisiana	1,183,855	586,339	16.0	12,095,285	3,096,630	54.3	1,255,768	620,196	37.6	2,876,526
Maine	1,321,588	647,254	29.1	717,071	363,235	20.5	857,745	437,122	1.1	192,061
Maryland	828,000	411,500	19.5	3,312,558	1,650,361	32.0	507,303	253,651	5.9	1,183,923
Massachusetts	1,666,144	830,246	19.9	2,354,116	1,171,638	16.1				3,029,708
Michigan	5,989,548	2,837,520	210.1	8,061,710	4,018,255	192.3	321,110	160,555	23.0	336,090
Minnesota	5,518,764	2,700,527	435.9	4,708,910	2,351,071	256.3	1,237,733	618,249	35.7	2,617,570
Mississippi	1,841,191	741,378	94.4	7,282,834	3,396,411	353.6	1,015,400	487,050	77.8	1,071,737
Missouri	3,269,557	1,621,353	162.0	7,819,816	3,647,187	201.1	4,413,377	1,859,252	122.1	2,489,791
Montana	4,086,765	2,313,548	283.3	2,202,220	1,242,712	116.7	725,003	409,119	40.7	2,896,871
Nebraska	3,253,483	1,620,730	381.6	5,210,812	2,506,645	616.1	1,860,467	930,233	198.3	1,798,163
Nevada	1,399,393	1,201,043	74.6	1,182,681	1,030,030	48.9	196,013	170,882	16.3	587,190
New Hampshire	1,445,362	707,199	36.4	416,295	206,110	9.0	3,500	3,500		911,881
New Jersey	1,378,600	687,344	9.4	4,948,640	2,474,320	35.4	2,888,629	1,444,265	19.2	401,152
New Mexico	2,000,830	1,217,833	169.6	1,448,445	873,122	53.8	116,106	81,786	16.3	932,261
New York	10,542,515	5,179,059	182.3	11,999,783	5,967,340	154.3	620,127	273,309	10.1	211,796
North Carolina	3,874,928	1,936,027	200.3	4,898,892	2,433,660	216.0	690,840	344,925	31.9	1,060,354
North Dakota	1,849,256	994,635	179.5	2,611,958	1,457,832	209.1	2,566,896	1,312,736	217.0	3,139,076
Ohio	4,635,036	2,317,158	60.4	11,954,352	5,952,982	100.9	7,591,170	3,716,422	63.2	1,499,572
Oklahoma	2,228,276	1,181,616	109.9	2,867,349	1,493,571	77.9	1,688,011	861,309	73.9	3,558,298
Oregon	3,099,420	1,852,951	152.6	2,152,775	1,146,386	38.0	1,180,535	642,233	43.4	373,462
Pennsylvania	5,380,364	2,660,383	73.0	12,208,079	6,052,002	106.1	3,138,000	1,567,035	18.1	899,689
Rhode Island	1,006,582	502,165	10.2	1,213,296	605,822	10.9				767,776
South Carolina	1,329,331	640,444	95.5	2,005,435	963,966	148.0	2,055,790	859,666	66.1	1,605,701
South Dakota	3,147,009	1,767,729	533.0	3,813,803	2,411,163	459.0	837,400	483,150	129.4	1,985,853
Tennessee	2,291,094	1,137,140	55.7	3,155,900	1,577,950	109.7	1,504,412	752,206	46.6	3,107,302
Texas	7,317,938	3,596,505	463.9	8,325,052	4,114,232	366.2	4,292,219	2,125,070	180.3	3,577,768
Utah	983,647	714,222	73.1	891,740	667,400	39.7	543,279	293,840	13.4	559,107
Vermont	1,163,682	581,760	36.6	621,508	308,948	15.9	617,939	308,860	17.1	80,899
Virginia	1,985,813	908,195	56.8	4,069,045	1,929,063	78.2	565,028	282,514	5.6	986,199
Washington	2,887,210	1,494,860	70.4	2,711,360	1,447,035	37.0	613,531	328,500	4.8	363,856
West Virginia	1,956,930	974,878	74.2	2,834,444	1,411,021	57.6	1,379,066	687,410	22.8	943,029
Wisconsin	5,222,868	2,554,057	179.1	1,998,484	989,335	88.9	781,748	374,103	14.1	3,063,486
Wyoming	1,770,996	1,107,603	196.2	980,178	619,650	120.0	347,489	222,114	24.4	498,504
District of Columbia	550,699	275,349	5.0	147,418	65,675	.5	597,519	267,200	1.1	115,144
Hawaii	116,159	54,200	1.7	683,726	347,860	10.2	165,944	96,472	2.5	1,463,503
Puerto Rico	137,846	68,065	2.7	1,586,876	785,205	25.5	196,527	96,495	3.0	621,005
TOTALS	143,910,886	73,272,565	6,514.4	204,332,269	100,614,516	6,222.2	65,166,435	32,272,328	2,254.7	74,009,336

STATUS OF FEDERAL-AID SECONDARY OR FEEDER ROAD PROJECTS

AS OF DECEMBER 31, 1940

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 190,944	$ 95,263	9.4	$ 1,303,357	$ 649,158	60.7	$ 5,000	$ 5,000		$ 276,238
Arizona	144,270	83,190	17.3	217,025	156,676	7.0				221,466
Arkansas	361,217	159,318	14.7	306,339	152,958	20.6	147,738	73,462	12.2	32,029
California	828,326	451,771	37.3	432,089	230,612	7.1	188,435	100,050	6.1	643,788
Colorado				298,599	167,773	6.9				122,450
Connecticut	370,531	179,413	4.6	105,456	49,907	1.8	126,629	56,207	2.6	109,035
Delaware	128,160	56,367	12.7	40,371	19,751	2.8				268,125
Florida	12,030	6,015		604,373	302,186	14.7	550,715	241,531	5.8	78,879
Georgia	118,120	58,526	15.6	777,663	373,831	63.3	363,156	181,578	37.0	1,000,215
Idaho	151,392	93,284	24.0	171,362	102,177	6.7	72,833	4,293	3.5	104,091
Illinois	1,605,055	791,594	80.3	1,038,750	504,375	28.5	271,500	131,550	16.5	104,114
Indiana	463,598	224,658	31.0	177,996	94,455	8.1	133,400	66,700	7.8	847,554
Iowa	2,193,253	1,039,631	464.3	689,523	328,000	187.0	284,278	123,275	86.2	56,021
Kansas	321,831	160,627	48.9	900,860	453,338	46.4	187,663	93,832	52.2	1,128,005
Kentucky	792,145	268,935	65.5	569,227	138,095	18.2	283,177	81,751	13.3	254,327
Louisiana	98,857	49,429	10.9	199,072	99,481	14.9				460,035
Maine	298,852	142,635	17.0	40,606	20,303	1.5				5,551
Maryland	94,300	47,150	3.5	132,390	66,195	6.5	36,000	18,000	4.3	385,314
Massachusetts	456,347	225,852	10.3	212,045	105,703	3.6				480,319
Michigan	1,447,559	715,572	112.3	347,480	173,740	29.1	590,520	288,230	41.2	292,245
Minnesota	641,778	315,634	86.8	742,976	371,488	116.8	290,629	145,314	37.7	765,584
Mississippi	172,962	86,481	10.6	717,352	353,176	39.0	366,200	160,615	14.3	435,223
Missouri	720,505	358,391	92.7	123,076	61,538	14.1	316,432	126,745	32.8	614,959
Montana	641,506	362,577	80.3	90,699	51,181	3.7	271,900	148,431	55.2	494,953
Nebraska	381,786	191,625	69.4	642,173	312,804	83.6	158,862	79,431	28.8	208,285
Nevada	201,288	172,834	40.9	175,048	152,379	14.3				8,573
New Hampshire	143,639	68,883	3.4	71,533	34,946	3.6				133,962
New Jersey	319,500	159,750	10.6	318,057	158,940	11.4				503,134
New Mexico	101,564	59,154	13.1	634,137	343,277	28.8	92,695	49,568	3.7	41,657
New York	1,698,625	805,985	52.5	1,654,255	827,127	55.4				77,918
North Carolina	941,132	468,665	82.2	225,403	115,313	25.5	151,390	75,695	14.6	219,706
North Dakota	42,880	24,583	.3	169,224	90,702	3.6				1,014,689
Ohio	1,263,398	631,633	46.5	2,199,455	1,098,468	67.0	160,375	80,187	9.9	677,442
Oklahoma	624,887	331,437	43.8	244,665	128,987	14.6	252,630	132,962	13.5	807,376
Oregon	372,237	205,770	56.4	180,645	74,674	13.4	192,677	98,260	18.2	161,630
Pennsylvania	1,418,725	701,839	51.0	940,699	469,441	19.2	224,936	112,468	4.7	147,408
Rhode Island	157,358	78,624	3.4	173,632	86,759	1.1				44,667
South Carolina	500,403	180,726	68.7	263,600	115,140	24.2	504,867	185,200	48.7	76,078
South Dakota				28,926	19,392	9.0				1,265,145
Tennessee	149,224	72,146	10.9	287,466	143,733	10.0				864,550
Texas	1,177,944	576,429	170.8	1,080,828	536,578	93.8	388,536	190,872	40.9	536,168
Utah	54,999	34,100	9.2	215,530	138,660	22.4	55,085	27,543	2.5	97,389
Vermont	346,351	112,834	13.1	196,176	57,330	7.6				4,391
Virginia	387,164	181,027	24.8	478,918	221,416	18.2	77,752	38,205	1.5	184,715
Washington	465,654	245,605	28.2	208,767	111,739	4.5	206,471	110,400	23.9	126,117
West Virginia	301,750	150,350	16.7	123,169	61,584	4.2	43,400	21,700	2.1	409,531
Wisconsin	330,613	164,243	7.4	636,776	318,310	23.2	369,473	141,704	16.1	496,435
Wyoming	429,615	253,344	42.8	153,530	95,100	9.1				70,846
District of Columbia	123,425	61,713	1.4	2,192	1,096					24,737
Hawaii	275,662	137,588	8.6	2,192	2,192					158,875
Puerto Rico	42,960	20,945	1.8	259,264	126,695	12.2	55,188	27,140	2.1	80,408
TOTALS	24,506,321	12,064,155	2,127.9	21,804,946	10,868,879	1,288.9	7,420,542	3,417,899	659.9	17,622,352

U. S. GOVERNMENT PRINTING OFFICE: 1941

PUBLICATIONS of the PUBLIC ROADS ADMINISTRATION

Any of the following publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. As his office is not connected with the Agency and as the Agency does not sell publications, please send no remittance to the Federal Works Agency.

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Report of the Chief of the Bureau of Public Roads, 1933. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1934. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1935. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1936. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1937. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1938. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1939. 10 cents.

HOUSE DOCUMENT NO. 462

Part 1 . . . Nonuniformity of State Motor-Vehicle Traffic Laws. 15 cents.

Part 2 . . . Skilled Investigation at the Scene of the Accident Needed to Develop Causes. 10 cents.

Part 3 . . . Inadequacy of State Motor-Vehicle Accident Reporting. 10 cents.

Part 4 . . . Official Inspection of Vehicles. 10 cents.

Part 5 . . . Case Histories of Fatal Highway Accidents. 10 cents.

Part 6 . . . The Accident-Prone Driver. 10 cents.

MISCELLANEOUS PUBLICATIONS

No. 76MP . . The Results of Physical Tests of Road-Building Rock. 25 cents.

No. 191MP. . Roadside Improvement. 10 cents.

No. 272MP. . Construction of Private Driveways. 10 cents.

No. 279MP. . Bibliography on Highway Lighting. 5 cents.

Highway Accidents. 10 cents.

The Taxation of Motor Vehicles in 1932. 35 cents.

Guides to Traffic Safety. 10 cents.

An Economic and Statistical Analysis of Highway-Construction Expenditures. 15 cents.

Highway Bond Calculations. 10 cents.

Transition Curves for Highways. 60 cents.

Highways of History. 25 cents.

DEPARTMENT BULLETINS

No. 1279D . . Rural Highway Mileage, Income, and Expenditures, 1921 and 1922. 15 cents.

No. 1486D . . Highway Bridge Location. 15 cents.

TECHNICAL BULLETINS

No. 55T . . . Highway Bridge Surveys. 20 cents.

No. 265T. . . Electrical Equipment on Movable Bridges. 35 cents.

Single copies of the following publications may be obtained from the Public Roads Administration upon request. They cannot be purchased from the Superintendent of Documents.

MISCELLANEOUS PUBLICATIONS

No. 296MP. . Bibliography on Highway Safety.

House Document No. 272 . . . Toll Roads and Free Roads.

Indexes to PUBLIC ROADS, volumes 6–8 and 10–20, inclusive.

SEPARATE REPRINT FROM THE YEARBOOK

No. 1036Y . . Road Work on Farm Outlets Needs Skill and Right Equipment.

TRANSPORTATION SURVEY REPORTS

Report of a Survey of Transportation on the State Highway System of Ohio (1927).

Report of a Survey of Transportation on the State Highways of Vermont (1927).

Report of a Survey of Transportation on the State Highways of New Hampshire (1927).

Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio (1928).

Report of a Survey of Transportation on the State Highways of Pennsylvania (1928).

Report of a Survey of Traffic on the Federal-Aid Highway Systems of Eleven Western States (1930).

UNIFORM VEHICLE CODE

Act I.—Uniform Motor Vehicle Administration, Registration, Certificate of Title, and Antitheft Act.

Act II.—Uniform Motor Vehicle Operators' and Chauffeurs' License Act.

Act III.—Uniform Motor Vehicle Civil Liability Act.

Act IV.—Uniform Motor Vehicle Safety Responsibility Act.

Act V.—Uniform Act Regulating Traffic on Highways.

Model Traffic Ordinances.

A complete list of the publications of the Public Roads Administration, classified according to subject and including the more important articles in PUBLIC ROADS, may be obtained upon request addressed to Public Roads Administration, Willard Bldg., Washington, D. C.

STATUS OF FEDERAL-AID GRADE CROSSING PROJECTS

AS OF DECEMBER 31, 1940

STATE	COMPLETED DURING CURRENT FISCAL YEAR					UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
			NUMBER					NUMBER					NUMBER			
	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	
Alabama	$ 28,328	$ 28,328			4	$ 739,788	$ 719,711	7	1		$ 91,839	$ 91,839	1		5	$ 828,568
Arizona	192,342	184,976	3			179,037	178,688	1			19,260	19,260			4	232,120
Arkansas	558,358	558,213	5	1	7	775,385	771,164	8		1	302,508	302,453	3		8	173,007
California	439,428	439,428	4		6	1,028,139	847,540	7	1		757,323	757,323	2		14	599,979
Colorado						288,868	288,868	1			7,698	7,698			3	911,326
Connecticut	622,002	611,366	5	1		166,222	165,415	2								449,334
Delaware	68,080	68,080			13	126,685	126,685	5		3	2,332	2,332			1	467,605
Florida	207,524	203,025	2		2	102,816	102,291	1	1		139,739	139,739			25	1,209,730
Georgia	178,317	178,222	4	1	12	1,083,508	1,083,508	10	6		253,372	253,372	1	2	6	1,748,913
Idaho	239,542	236,113	5		16	34,107	34,107			6	43,471	43,471			15	401,036
Illinois	1,316,578	1,251,451	6	1	33	1,658,356	1,439,032	7	1	77	230,347	220,571	1		47	1,887,208
Indiana	578,286	578,286	3	2	50	629,262	629,262	4		40	392,007	359,107	1	1	11	661,505
Iowa	453,405	390,966	4		74	182,658	153,233	2		18	173,571	172,562	2		12	1,076,739
Kansas	687,637	687,530	9		14	303,791	303,313	3	1	4	535,580	535,580	11	1	10	727,701
Kentucky	573,093	572,549	8		11	637,876	637,876	7		1	382,102	343,702	2		4	240,666
Louisiana	95,496	95,496	1			345,122	291,627	2			632,768	575,037	11		2	811,244
Maine	159,759	158,841	1	1	6	132,646	132,646	1	1							263,934
Maryland	180,996	180,994	1		2	476,609	444,816	2	2	5	15,600	15,600			3	767,315
Massachusetts	15,710	15,710				343,592	333,170	1	1		90,040	89,740	1			1,928,300
Michigan	1,113,805	1,080,491	8	1	30	1,474,965	1,474,965	2	5	7	16,907	16,907			4	608,530
Minnesota	1,104,508	1,096,651	8	2	10	1,009,381	1,009,381	9	4	9	120,707	120,707		1	1	1,009,369
Mississippi	198,260	198,260	3			654,334	654,334	8	1		74,000	74,000	1		4	506,072
Missouri	1,208,389	1,208,389	6	5	1	1,709,501	1,254,081	5	1		222,144	137,078		2		901,314
Montana	427,675	427,675	5		2	88,047	88,046	1			9,155	9,155			3	344,634
Nebraska	230,657	228,986		1	9	993,774	993,774	15	1	1	143,457	143,457	2		12	158,591
Nevada	30,569	30,569			19	109,892	109,892	2			75,953	75,953	1		6	56,527
New Hampshire	100,989	100,953	3			149,458	148,638	3		1						331,169
New Jersey	269,185	269,185	2			596,798	596,798	3	1	4	264,880	264,880	1			932,729
New Mexico	242,979	242,979	2		6	183,821	175,247	3								479,380
New York	1,207,716	1,173,326	7	5		3,007,233	2,956,562	5	15		953,770	673,194	2	2	8	2,431,309
North Carolina	478,532	478,469	7	2	15	709,829	709,589	7	4	7	173,490	173,490		2	31	718,553
North Dakota	471,940	471,755	5		22	385,820	385,820	4		1						529,158
Ohio	811,713	789,951	6		16	2,143,380	2,084,190	9	3	1	865,625	850,163	5			2,065,990
Oklahoma	458,066	457,039	8	1	29	483,662	478,899	5		2	115,665	115,665			39	1,878,750
Oregon	208,639	117,537	3			254,208	197,981	1			86,974	80,790	2		2	290,984
Pennsylvania	1,387,269	1,377,793	13	2		2,021,009	2,017,181	14			872,546	872,546	7			2,621,372
Rhode Island	3,831	3,750				210,359	210,359		1							77,347
South Carolina	404,780	404,377	4	3	11	108,503	108,503	1		9	261,042	260,442	2		34	815,336
South Dakota	129,470	129,470	2	1	4	528,394	527,534	14			101,060	85,110	2			798,806
Tennessee	244,886	241,169	2	2		166,727	166,727		2		162,270	153,270	3	1		1,567,057
Texas	1,271,717	1,266,909	11		9	1,128,378	1,118,013	10	1		437,480	380,020	6		2	1,635,493
Utah	25,565	25,354			7	68,776	68,034	2		23	100,989	100,989			38	220,805
Vermont	101,024	101,024		1	4	148,111	148,111		1	5	8,182	8,182			3	213,187
Virginia	150,174	149,598	2	2	5	665,853	664,763	5	1	2	193,314	193,314	1	2	8	497,887
Washington	241,001	238,049	3	1	6	585,391	576,290	4	3		68,608	68,608		1	7	73,061
West Virginia	5,400	5,400			2	303,002	299,552	4			118,450	116,890	1		1	958,310
Wisconsin	834,332	819,761	6	4	7	452,980	423,971	3		4	127,215	117,651	1		14	1,262,972
Wyoming	1,987	1,982				560,905	560,904	6			4,997	4,997			2	166,634
District of Columbia	56,868	56,868	1			2,193	2,193									176,925
Hawaii	4,810	4,810			1	196,229	196,221	2			4,684	4,684			1	290,316
Puerto Rico						584,007	579,336	11								414,857
TOTALS	20,021,617	19,638,103	178	40	465	30,919,387	29,668,841	229	59	231	9,653,121	9,031,528	73	15	390	40,419,654